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# Effects of computer self-efficacy and spatial visualization ability on student perceptions of 2D/3D CAD virtual prototype simulations for apparel design

Sandra Stewart  
*Iowa State University*

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**Effects of computer self-efficacy and spatial visualization ability on student perceptions of 2D/3D CAD virtual prototype simulations for apparel design**

by

**Sandra Stewart**

A thesis submitted to the graduate faculty  
in partial fulfillment of the requirements for the degree of

**MASTER OF SCIENCE**

Major: Textiles and Clothing

Program of Study Committee:  
Jean Parsons, Major Professor  
Sara Kadolph  
Shana Smith

Iowa State University

Ames, Iowa

2008

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## **ABSTRACT**

The ability to visualize three-dimensional (3D) forms from two-dimensional (2D) shapes is critical to apparel designers. While most designers still use traditional techniques to analyze a 3D sample, advances in CAD for apparel design include use of 3D virtual prototypes assembled from 2D pattern data. Textiles and clothing research has examined both 2D CAD and student spatial visualization ability, but no studies compare spatial visualization ability with 3D virtual prototype use in the classroom. Other fields of research have found that a person's computer self-efficacy (CSE) can influence acceptance of a new technology and that spatial visualization ability can determine effectiveness of 3D simulations.

The purpose of this study was to examine the influence of CSE and spatial visualization ability on student perceptions of 3D virtual prototyping software. An online test instrument measured: CSE, general spatial ability and apparel spatial visualization ability with tutorial was developed to introduce participants to 3D virtual prototyping software. Some volunteers also participated in a hands-on session for actual use of the software. Technology acceptance was measured after the tutorial and again after the hands-on session.

Individuals with high CSE found the software easier to use than individuals with low CSE. Individuals with high apparel spatial visualization ability found the software easier to use than those with lower apparel spatial visualization ability. Other findings and discussion provide information that could help both educators and industry plan for the effective use of 3D virtual prototypes.

## **CHAPTER 1: INTRODUCTION**

The purpose of this study is to examine the influence of computer self-efficacy and spatial visualization ability on student perceptions of 2D/3D CAD virtual prototype simulations for apparel design. The following sections will provide an overview of why spatial visualization ability is critical in the context of apparel design and how it is related to both current and future use of computer-aided design technologies. The relevance of computer self-efficacy will be introduced. The purpose of the study will be described in more detail, with five objectives defined. Definitions of relevant terminology will be stated, as well as the research hypotheses.

### **Overview**

Apparel design is very much a visual process from concept to prototype. An apparel design student will frequently be asked to initially observe trends and/or to do other visual research from a variety of sources before they can first imagine or visualize a concept for their own original garment design. The student may then be expected to make a two-dimensional (2D) sketch of their design concept based on the three-dimensional (3D) visualization. A design may also evolve through hands-on 3-dimensional experimentation on a body form, with or without an initial sketch. From a 2D sketch the student must begin the patternmaking process, either by 2D-to-3D flat pattern drafting, by a 3D-to-2D draping process, or a combination of the two. For example, the bodice of a garment may be designed in 3D using muslin on

a body form, applying draping techniques to create a prototype garment. That muslin prototype is then used to draft 2D flat patterns for the draped bodice design. At the same time, the sleeve for the garment may have been drafted as a 2D flat pattern, and then tested in 3D form.

Spatial visualization skills also are required during the marking and cutting of sample patterns from fabric, for determining the number of pieces needed, which is the left, right, front, back, and the direction to cut on the fabric. The construction process requires further spatial visualizations when the student must determine how 2D pattern pieces will be sewn together and in what orientation they must be for correct folding and pressing of 3D design elements, such as pleats and darts.

Once the prototype is finished, a visual inspection of the fit requires the garment to be placed on a body form or a live model. Multiple prototypes and repeated fit sessions may have to occur before the finished garment is visually similar to the designer's first 2D concept sketch and comfortably fits a 3D figure. In production environments that sample garment is then sized up and down, called grading, so that the garment can be created in a full size run. The grading process yet again requires spatial skills in regard to appropriate growth between sizes and the polarity of X & Y coordinates when modifying the graded pieces.

Apparel industry specific computer-aided design (CAD) software has taken a similar route from 2D to 3D in its development. What began as simply digitizing 2D flat patterns for computerized cutting of multiple plies of spread material, has evolved to software suites with design, patternmaking, grading and marking modules that can help the designer create, grade, mark and exchange 2D pattern data with

ease (Gray, 1998). In recent years apparel CAD has come to include advanced tools for simulating the construction of a virtual prototype, using the 2D pattern data and cloth animation algorithms to construct the sample garment on a virtual 3D model.

As advances in CAD technology are made, more and more visual apparel design and analysis, from concept to prototype, is done on the computer. The use of CAD software has become a daily task for many apparel designers, with CAD technology widely accepted by the sewn goods industry during the last decade. While working as a CAD application specialist, training members of the sewn goods industry, it was apparent to me that people have different skills and perceptions related to use of CAD. Many trainees had very limited computer skills, but advanced knowledge of the components and shapes of sewn goods. Other trainees had advanced computer skills, but limited experience working with the basic blocks and pieces that make up a sewn product. For some, learning simple digitization and manipulation of 2D patterns was time intensive and difficult, while others learned quickly and showed potential to become advanced system users.

Typically, challenges that all trainees experienced were simply related to learning the layout and proper navigation of the menu and functionality. But difficulty also arose from the transfer of manual skills to a digital space, including manipulating or moving pieces on an X & Y axis, and mirroring, rotating or zooming in on the 2D pieces. With practice and continued exposure to the system, trainees eventually become confident daily users of a sophisticated CAD system. All trainees



also become very familiar with the identification and manipulation of the 2D pattern pieces required for construction of the finished product.

Within the last few years, apparel industry CAD has advanced even further, offering 3D virtual prototype simulations. These simulations typically require the user to specify 2D pattern piece locations in relation to the body, such as “front,” “back,” “right,” and “left,” as well as identify and match seams that are sewn together during construction. The 2D patterns are then placed on a 3D body model, and a simulation of the assembly and drape results in a virtual prototype. The virtual prototype can be closely examined, with many variations in perspective and rotation of the 3D model allowed. Virtual prototyping of this kind has the potential to speed up the sample approval process considerably, with initial pattern, construction and fit problems identified and corrected on the digital flat patterns before any fabric is cut.

There are a few small and large firms testing the use of this new technology in their design and product development departments, however it has yet to become widely accepted by the apparel industry. While attending an industry software user’s conference a few individuals made comments to me that were somewhat pessimistic about the technology. Those individuals were quite skeptical of 3D CAD and thought of it as a “gimmick” without any true usefulness, or if they did recognize the usefulness, they suggested that the software was too complex to be introduced to and utilized by average CAD users.

Similar to industry, 2D CAD patternmaking software is in wide use in college and university apparel design programs but only a few have started to use 3D CAD. OptiTex’s 2D/3D CAD is one of the more recently adopted for use in apparel design

programs, such as at Cornell University, University of Minnesota and Parsons School of Design (“OptiTex,” 2007). Students in Parsons School of Design use OptiTex’s 3D virtual prototyping software to assemble their digitized patterns into virtual garments and participate in simulated fit sessions (Crawford, 2006).

Today’s college students are part of the “Net Generation,” individuals deemed “digital natives” that were born at the time of the PC (1981 – 1995) and grew up with the internet (Oblinger & Oblinger, 2005). These students have been found to be “tech savvy” with expectations for working with visually rich, cutting edge software (Crawford, 2006). Scholars with backgrounds in teaching and learning have found that students from the Net Generation are more visually literate than previous generations, preferring experiential learning utilizing simulations and visualizations rather than text heavy lectures (Oblinger & Oblinger, 2005).

As a graduate teaching assistant working with these students on basic skills in 2D CAD patternmaking and computer-aided textile design, I feel that virtual prototype simulations could be very useful and well received in the classroom. The CAD skill level of the incoming students is surprisingly high, with many of the students already having worked with off-the-shelf design software, such as Adobe Photoshop, in high school. Use of virtual prototype simulations could be very useful for students who may have moderate confidence in their computer skills, but have difficulty visualizing a 3D garment from 2D patterns, or vice versa. Use of the software at a beginning level could potentially improve pattern shape knowledge and visualization skills. Use at an advanced level could allow students more options for evaluation of design and issues related to fit.

While exploring current issues and research in the realm of technology and textiles and clothing, studies were found related to virtual models used in e-commerce, and on the development and improvement of 3D virtual prototyping software (Lee, Fiore & Kim, 2006; Eischen, May-Plumlee, Kenkare, & Pandurangan, 2003). No research in the field of textiles and clothing has addressed the use of 3D virtual garment prototypes in classroom instruction. Research related to use of 3D CAD in the classroom has been done in the field of engineering, with a focus on student spatial visualization abilities (Sorby, 2000). There has also been scholarship in the field of architecture and construction engineering education related to the classroom use of advanced 3D modeling (Snoonian & Cuff, 2001; Rubenstone, 2007). Textiles and clothing scholars, Workman, Caldwell and Kallal, (1999) have researched apparel spatial visualization abilities in a 2D environment, but no studies have examined how spatial abilities may influence visualizations in a 3D environment.

Current students in all design fields not only need to have spatial visualization skills, they also need to be able to transfer them to a digital environment. A curriculum that focuses on increasing the amount of confidence a student has in their visualization and digital design skills would create graduates highly valuable to industry.

### **Purpose of Study**

Because of the high cost, in both time and money, associated with the implementation of advanced 2D/3D CAD technology in the classroom, it would be

beneficial to understand what factors potentially relate to both acceptance of and effectiveness of the technology as a teaching tool for apparel design. In addition it is critical to identify best practices for introducing the technology to students for maximum learning and understanding. The purpose of this study is to test whether a student's computer self-efficacy and spatial visualization ability impact their perceptions of 3D virtual prototyping software, specifically the perceived ease of use and usefulness. The results could potentially demonstrate at what level of student experience the software would be most accepted and most effective as a learning tool. This information could help both educators and industry plan for the implementation of advanced 3D CAD technology. Surveys assessing computer self-efficacy and spatial visualization ability could be used for curriculum development and as gateways to advanced design courses.

### **Objectives**

Objectives were developed based on findings from a pilot study and from review of literature. Davis's (1989) research on technology acceptance inspired a need to assess perceived ease of use and perceived usefulness of 3D virtual prototype simulations. Venkatesh and Davis's (1996) findings on the influence of computer self-efficacy on perceived ease of use suggested a need for assessment of computer self-efficacy among apparel design students. Thus, the objectives of the research are:

1. To assess the computer self-efficacy of textiles and clothing apparel design students.

2. To assess general and domain specific spatial visualization skills of textiles and clothing apparel design students.
3. To develop a 2D/ 3D CAD virtual prototyping software tutorial.
4. To assess student perceptions of ease of use and usefulness of 3D virtual prototyping software after exposure to the tutorial.
5. To assess student perceptions of ease of use and usefulness of 3D virtual prototyping after exposure to the tutorial followed by hands-on interaction with the software.

### **Definitions**

The following terms and definitions will be used throughout the thesis. The first two are defined as generally used in the apparel industry and the remaining cite published definitions.

*2D CAD*: Computer-aided design software which allows for digitizing, drafting and manipulation of flat (2D) patterns

*3D CAD virtual prototype*: 2D CAD patterns assembled and draped on a 3D model for simulation of a constructed virtual prototype garment

*Computer Self-Efficacy*: “A judgment of one’s capability to use a computer which greatly impacts an individual’s expectations of computer use and competency” (Compeau & Higgins, 1995, p. 192).

*Spatial visualization*: “The ability to mentally manipulate an entire spatial configuration, to imagine rotation of depicted objects, to imagine the folding or unfolding of flat patterns, and to imagine the relative changes of position of objects in space.” (McGee, 1979, p. 17).

*Perceived Ease of Use:* An influential factor in technology acceptance defined as “the degree to which the prospective user expects the target system to be free of effort” (Davis, 1989, p. 320).

*Perceived Usefulness:* An influential factor in technology acceptance defined as “the prospective user's subjective probability that using a specific application system will increase his or her job performance within an organizational context” (Davis, 1989, p. 320).

### **Hypotheses**

Eight null hypotheses were formulated based on findings from a pilot study and findings from the review of literature. The hypotheses are intended to support the objectives of the study and provide findings beneficial for use by educators.

H<sub>0</sub>: Computer self-efficacy will have no impact on student perceptions of the ease of use of the 3D virtual prototyping software.

H<sub>0</sub>: Computer self-efficacy will have no impact on student perceptions of the usefulness of the 3D virtual prototyping software.

H<sub>0</sub>: General spatial ability will have no impact on student perceptions of the ease of use of the 3D virtual prototyping software.

H<sub>0</sub>: General spatial ability will have no impact on student perceptions of the usefulness of the 3D virtual prototyping software.

H<sub>0</sub>: Apparel specific spatial ability will have no impact on student perceptions of the ease of use of the 3D virtual prototyping software.

H<sub>0</sub>: Apparel specific spatial ability will have no impact on student perceptions of the usefulness of the 3D virtual prototyping software.

H<sub>0</sub>: Student perceptions of the ease of use of the 3D virtual prototyping software will not differ under the two conditions: exposure by tutorial only vs. exposure by additional hands-on session.

H<sub>0</sub>: Student perceptions of the usefulness of the 3D virtual prototyping software will not differ under the two conditions: exposure by tutorial only vs. exposure by additional hands-on session.

## **CHAPTER 2: LITERATURE REVIEW**

### **Introduction**

A review of literature was completed to provide a background for the study. The review begins with a summary of relevant literature on the topics of technology acceptance and computer self-efficacy. Literature on general spatial ability was reviewed as well as spatial visualization abilities specific to apparel design. An overview of current applications of 2D and 3D CAD in the apparel industry and apparel education is provided. The review is concluded with a summary of literature related to the influence of spatial visualization ability on CAD and CAD simulations in the context of education.

### **Technology Acceptance Model**

In research related to technology, a commonly cited theoretical model is the Technology Acceptance Model (TAM) developed by Davis (1989). Davis's (1989) TAM is an adaptation of the Theory of Reasoned Action (TRA), a model developed by social psychology researchers to predict and explain behavior, and applied generally to many different domains. The TAM specifically focuses on behavior related to technology acceptance, and defines perceived usefulness and perceived ease of use as two relevant variables (Davis, 1989). Davis (1989) defines perceived usefulness as "the prospective user's subjective probability that using a specific application system will increase his or her job performance within an organizational



context,” and perceived ease of use as “the degree to which the prospective user expects the target system to be free of effort” (pg. 985).

Much of the initial use of TAM in research was done in the field of management information systems. However, more recently TAM has been used in studies related to technology use in the fields of human computer interaction, electronic commerce and education (Davis, 1989; Morris & Dillon, 1997; Pavlou, 2003; Gao, 2005; Ma, Andersson & Streith, 2005). In these studies, typical application of the technology acceptance model requires a research design in which participants are exposed to technology and test instruments including Davis’ scales to measure the perceived usefulness and perceived ease of use. As with the TRA, the TAM is often used to explain both behavioral intention to use and actual usage. Similarly, in the field of textiles and clothing, TAM has been applied in studies of consumer attitude toward and behavior intentions related to online commerce (Lee et al., 2006). Studies have also used TAM without the specific purpose of predicting attitude or behavior; instead the research focuses on determining factors that influence perceived ease of use and perceived usefulness.

### **Computer Self-efficacy**

Venkatesh and Davis (1996) state that understanding antecedents of perceived ease of use is important for explaining technology acceptance. Their research determined one antecedent as computer self-efficacy (CSE). Computer self-efficacy literature recognizes Bandura’s Social Cognitive Theory and the construct of self-efficacy, generally defined as what a person perceives their

capabilities to be with regard to a specific task (as cited by Compeau & Higgins, 1995; Marakas, Yi & Johnson, 1998; Khorrami-Arani, 2001).

In the case of technology, self-efficacy is made more specific by focusing on a person's perception of their ability to complete a computer task. Compeau and Higgins (1995) define computer self-efficacy as "a judgment of one's capability to use a computer" and developed a measure adapted from an earlier scale. CSE can be used to predict user acceptance of technology and results of CSE studies could be used to improve introductions or trainings so that acceptance of new technologies is increased (Venkatesh & Davis, 1996).

### **Spatial Ability / Spatial Visualization**

A review of literature finds that the term "spatial visualization" is often interchanged with or noted as a subfactor of a broader term "spatial ability" (Gitimu, 2005; Pak, Rogers & Fisk, 2006; Strong & Smith, 2001-2002). Research by Eliot and Smith describes spatial ability as a term with many different definitions but in general it can be thought of as the way in which individuals process non-linguistic information (as cited by Gitimu, 2005; Strong and Smith, 2001-2002). Strong and Smith (2001-2002) describe new spatial ability research emerging from the field of engineering graphics, which is concerned with the relationship between spatial visualization skills and computer technology.

Measurement of spatial ability was done by paper and pencil tests as early as the 1930s (McGee, 1979). Hundreds of tests exist that measure various spatial abilities, and generally their scores can be used to predict successful problem

solving in technical and artistic occupations (Gitimu, 2005). In the age of computer graphics, Strong and Smith (2001-2002) suggest that adaptation of these tests to an online format, specifically taking advantage of 3D graphic technologies, would provide more opportunities for collection of data. A limitation of the existing tests is that they measure general spatial abilities rather than field or domain specific skills (Workman et al., 1999).

As a subfactor of spatial ability, spatial visualization has a definition that is more specific. McGee (1979, p. 17) defines spatial visualization as “the ability to mentally manipulate an entire spatial configuration, to imagine rotation of depicted objects, to imagine the folding or unfolding of flat patterns, and to imagine the relative changes of position of objects in space.” Scholars have indicated that spatial visualization skills are important in technology related disciplines making use of computer-aided design (Gitimu, 2005; Pak et al., 2006; Sorby, 2000; Strong & Smith, 2001-2002). General spatial visualization ability has been measured by the surface development test from Ekstrom, French, Harman and Dermen (1976). Domain specific apparel spatial visualization ability has been measured by the Apparel Spatial Visualization Text (ASVT), developed by Workman et al. (1999).

### **Spatial Visualization in Apparel Design**

In *Visual Design in Dress*, Davis (1980, p. 73) stated that a designer “must be able to look at a flat pattern piece and envision how it will look made up, to look at a sketch or an actual model garment and visualize how many and what shapes and sizes of flat pattern pieces are needed for that garment.” Spatial visualization skills

are necessary for imagining a 3D view of a 2D garment sketch, and for the manipulation and adjustment of flat pattern pieces to reflect style or fit changes (Workman et al., 1999). Even loosely sketching a garment requires the designer to interpret 3D shapes, such as a conical sleeve, which becomes a 2D trapezoid in a flat sketch (Workman & Lee, 2004).

Because of the importance of spatial abilities in the field of apparel design, a test was developed that measures domain specific spatial visualization skills (Workman et al., 1999). The Apparel Spatial Visualization Test (ASVT) consists of 20 sets of pattern pieces and groups of garment sketches. The subject must determine which garment sketch (out of a group of five) can be constructed from the set of pattern pieces shown. Validity of the test has been conducted by comparing scores of subjects from the ASVT with scores on three tests of general spatial abilities: the DAT:SR, the Surface Development Test, and the Paper Folding Test (Workman & Caldwell, 2007).

In the first ASVT study, the sample population consisted of 49 clothing and textiles students, and comparisons were made based on the students' prior clothing construction or patternmaking training. Results ranged from 2 to 20 with the mean score as 12.55, and it was found that students with prior training scored significantly higher ( $M=14.76$ ) than those with no training ( $M=7.57$ ) (Workman et al., 1999). A second ASVT study found that the mean score of clothing and textiles students who had completed training on CAD for patternmaking was significantly higher ( $M=18.70$ ) than the mean score of students ( $M=13.33$ ) who had completed manual patternmaking training only (Workman & Zhang, 1999).

## **2D/3D CAD use in the Apparel Industry and Apparel Education**

What used to be a manual process, from a designer producing a concept sketch, to drafting the patterns by hand, and then to final construction of a sample garment, now has the potential to become a completely digital process. However, the apparel industry was relatively slow to adopt computer technology, particularly at the design and development stages (Gray, 1998). With computerization of the patternmaking process in the late 1970s, the apparel industry slowly adopted the technology, and many of today's younger apparel designers don't remember a time without the use of 2D CAD (Thiry, 2006). The introduction and acceptance of 3D CAD tools can be expected to have the same gradual growth within the apparel industry. In 2004, advanced 3D prototyping technology was reportedly still in the early stages of adoption by the apparel industry (DesMarteau & Speer, 2004).

With 3D CAD software, creative and technical designers can simulate the fit and drape of apparel on a virtual model, without wasting time and materials on designs that may require lots of troubleshooting and numerous live model fit sessions before a sample garment can be approved for production (Speer, 2005). Researchers in Cornell University's Body Scan Research Group found that substituting 3D virtual models for live fit models in the fit analysis process was highly successful, with benefits such as ability to hold virtual fit sessions with participants in remote locations and having access to the recorded session for later analysis, including rotated and enlarged views (Ashdown, Loker, Schoenfelder & Lyman-Clarke, 2004). Apparel Magazine's roundtable discussion with industry participants on the issue of garment fit illustrates an agreement that 3D visualization tools are

useful for communicating fit problems and issues with construction details (DesMarteau, 2005).

The eventual wide-scale adoption of CAD software by the apparel industry has influenced educators to provide training on industry-specific CAD software as part of their professional development (Yan & Fiorito, 2002). As early as 1992 research was done on effective use of a design tutorial to introduce CAD use into a manual flat pattern design course (Belleau, Orzada, & Wozniak, 1992). Many university apparel design programs began introducing or fully using CAD in their instruction of flat pattern by 1996, when it was also speculated that apparel design programs would begin using more computer-aided instruction (CAI) modules for pattern design tutorials (Koch, 1996). Students at Parsons School of Design now use apparel industry specific 3D CAD software to assemble their digitized patterns into virtual garments and participate in simulated fit sessions (Crawford, 2006).

Now that the apparel industry is starting to use both 2D and 3D CAD, presumably, apparel design education programs will begin to explore the use of 3D CAD and develop appropriate CAI modules to introduce students to the technology. Not only can 3D software be used directly by students, such as at Parsons, but also there is potential for the output of 3D visuals that could be used in somewhat less advanced, but still interactive, CAI modules. CAI modules often adapt advanced computer-based visualization graphics for academic use, enabling students to build virtual models that can be rotated in ways that aid in visualization and problem-solving (Bransford, Brown & Cocking, 2000, p215). One study in the field of textiles and clothing included the development of an interactive CAI model which guided

students from views of 2D patterns to 3D visuals of the resulting style (Kallal, Sharp, & Orzada, 1999).

Workman and Zhang (1999) state that to prepare successful designers, educators must know what types of exercises aid in improvement of visualization skills, and they, as well as Gitimu (2005), suggest that certain levels of spatial visualization ability may be necessary for successful use of computer-aided design. Even though CAD and CAI has been introduced in the clothing and textiles curriculum, there has been little research on the attitudes of students toward the use of CAD or on factors related to the effectiveness of CAI (Frey, 1995; Marshall & Slaybaugh, 1986; Slocum & Beard, 2005).

### **Spatial Visualization Related to Use of CAD and CAI**

Scholars from the fields of education and psychology have proposed that a student's spatial ability plays an important role in their ability to perform computer-based tasks (Norman, 1994; Pak et al., 2006). In addition, engineering graphics researchers have recently questioned whether levels of spatial visualization ability influence the use of advanced computer-aided design technology (Strong & Smith, 2001-2002). There has also been scholarship in the field of architecture and construction engineering education related to the classroom use of advanced 3D modeling (Snoonian & Cuff, 2001; Rubenstone, 2007).

A student's spatial ability can be related to effective instruction of 3D CAD or use of CAI modules (Sorby, 2000; Huk, Steinke, & Floto, 2003). It could be hypothesized that students with lower spatial abilities would benefit from 3D

simulations due to the challenge they may have visualizing the images themselves. However, research has found that participants with high spatial ability had more positive attitudes toward 3D simulations than students with lower spatial ability (Huk et al., 2003). Studies have indicated that training increases spatial (Olkun, 2003; Scribner & Anderson, 2005; Workman et al., 2007).

While these studies essentially strive to measure the benefits related to the use of CAD and CAI in instruction, it is also prudent to study student perceptions of the technology's ease of use and usefulness. If a student does not find computer-aided design software or computer-aided instruction modules easy to use, or see the usefulness pertaining to their field of study, then there is little benefit to their use during instruction.



## **CHAPTER 3: METHODS**

To meet a general objective of assessing and measuring student spatial abilities, a pilot study was performed. The pilot study results and its application to this research are discussed in the first section of this chapter. The process of selecting and acquiring 2D/3D CAD software is also described. A major objective of the study was to develop a 3D virtual prototyping tutorial. Both the method and goals of the tutorial development are explained in detail. Creation of the online survey instrument, critical to the study, is also described. A summary of the research design is provided, as well as methods for data collection and analysis.

### **Pilot Study**

I completed a pilot study to measure student visualization processes in Spring 2007. The general purpose of that study was to observe and assess textiles and clothing student learning experiences and spatial abilities at different course levels. Results of this study were used as preliminary research on the influence of a student's spatial ability on the perceived ease of use and acceptance of 2D-to-3D CAD simulations in instruction of apparel design, and to further determine objectives for thesis research.

The primary objectives of the pilot study were to observe visual learning in apparel design students at several levels of design courses; to measure interest in advanced technology and comfort in learning CAD; and to compare apparel spatial visualization test scores of students at different levels of experience. Participants in

the study were 73 undergraduate university students majoring in textiles and clothing. The students were currently enrolled in one or more patternmaking or design courses ranging from beginning to advanced. There were 69 females and 4 males, with an average age of 21 years.

I performed non-participant observations, and recorded field notes during both levels of patternmaking courses in order to assess visualization techniques used during instruction as well as student use of spatial abilities in the classroom. For each course, an average of 120 minutes of observation was done throughout the semester. Qualitative analysis included identification of themes in the field notes and summarization from the perspective of the observer.

A 20 item quantitative survey was developed and included ten items requesting demographic and prior experience information, and ten items requesting the participant to rate either “Strongly Disagree,” “Disagree,” “Neutral,” “Agree,” or “Strongly Agree” on issues pertaining to technology, visual learning, and self-perceived visualization skills.

Following the survey, students completed Workman, Caldwell and Kallal's (1999) Apparel Spatial Visualization Test (ASVT) as a measure of domain specific spatial ability. The ASVT consists of 20 sets of pattern pieces which can be constructed to form one of five garments represented by a flat sketches. Participants must decide which labeled garment sketch can be made from the pattern pieces shown, circling the corresponding letter for each set as listed on a separate answer sheet. No time limit was specified.

While some of the observation occurred early in the semester, the survey and ASVT testing took place at the end of the semester using participant volunteers from three different groups, students enrolled in either Patternmaking I, Patternmaking II, or Computer Integrated Textile and Apparel Design. Several students were also enrolled in other design courses including Technical Design Processes; Experimental Design and Presentation; and Advanced Apparel Design.

Students in the first group, Patternmaking I, learned basic flat pattern and draping methods by live instructor demonstrations which were video projected onto a five foot square screen. Patternmaking I students were briefly introduced to a CAD patternmaking software program near the end of the semester. Students in the second group, Patternmaking II (for which Patternmaking I is a prerequisite), received instruction in advanced flat pattern and draping methods, as well as approaches to troubleshoot fit problems. Both courses use *Patternmaking for Fashion Design* and *Draping for Apparel Design* by Helen Joseph-Armstrong as the textbooks, and include projects requiring students to sketch a concept garment, create the appropriate patterns, construct a fit sample garment in muslin and complete a finished garment that is presented to the class in the form of a design critique.

The third group consisted of students in the Computer Integrated Textile and Fashion Design course, for which the patternmaking courses are not a prerequisite. However in this sample, all students in the third group indicated concurrent or previous enrollment in Patternmaking II, and other design courses. The course focused on CAD skills necessary for collection presentations of textile designs filled

into flat sketches and digitally draped on illustrated or photographed fashion figures. This course does not use 2D CAD for patternmaking or do any hands-on 3D design development. Although three groups were surveyed, the focus of the research was on the difference between students in Patternmaking I (Group 1) and Patternmaking II (Group 2).

Observations made of students during the two levels of patternmaking instruction were useful for a basic understanding of the opportunities students had for visual learning. In Patternmaking I (Group 1), instructor demonstrations were projected on a video screen and usually consisted of exercises out of the textbook, with the corresponding pages noted. Students were encouraged to first watch and listen and then follow along with the repeated demonstration. Generally, two or three different demonstrations were done by the instructor and then the students were given time to practice the same exercises on their own half-scale patterns. While many students watched the demonstration as it was projected on the video screen, several also referred to the visuals in their open book, or looked elsewhere.

During the practice time, the instructor answered questions and helped as needed. Many students hesitated before starting, and watched to see what steps their neighbors took to get started. One student asked another, "How can you remember how she did that so well?" to be answered with, "I'm looking in the book." As more students began working with their half scale pattern blocks, rotating darts and taping onto paper, many of them were observed lifting the paper up and looking very closely as they lined up dart legs to fold. "Which way do we fold the excess?" was asked repeatedly, even though the instructor had reminded the class that the

“fold goes toward center front” several times. The students examined the resulting 3D shape closely as they carefully cut along the closed contour, and often appeared surprised to see the shape of the resulting dart cap when the pattern was unfolded and two dimensional once more. “Is there supposed to be this little cut-out at the cap... I thought they [darts] all had the little triangle cap?”

Students in Patternmaking I appeared to use several different visual stimuli in their learning: the instructor’s demonstrations, the visuals in the textbook, and the work of their fellow classmates. Many of the students seemed to have little prior knowledge of basic two dimensional pattern shapes, and the changes that occurred due to style modifications such as dart rotations, i.e. visualization questions in the nature of “Is it supposed to look like this?” were typical. Students needed reminders in regard to direction of folds and advice with the order of assembly during construction of project garments.

In Patternmaking II (Group 2), demonstrations were done by the instructor on a body form or at a table in the front of the class. There was no video projection, so the students gathered around the instructor during the demonstration.

Corresponding pages in the textbook were noted. While a few students brought paper and pencil for taking notes, the majority did not. Students then returned to their assigned body forms and repeated the draping exercise with muslin. The instructor’s example is left at the front of the classroom as a reference.

Occasionally a student came back to the instructor’s example to compare to what they started on their own body form, but the majority referred to their textbook or glanced at what their neighbors were doing. The instructor went about the

classroom to answer questions and often had to unpin and readjust the muslin on the student's dress forms during the explanation. Sometimes there were students with questions that had to wait, and a system of writing names on the board was implemented so that instructor knew whom to go to next.

Students were also observed during preparation for their first design project. While several students continued to drape muslin and make adjustments on the form, many used 3D to 2D skills to draft the flat patterns and cut out them out of sample fabric. The next step was to assemble the cut 2D fabric pieces into a 3D physical prototype. Two students discussed their preliminary efforts at planning the construction the sample garment:

Student 1: "Okay, I think I've got this figured out... it is about mental images."

Student 2: "I know, I get so confused... [points to two cut pattern pieces] so this would go there and then I will turn this and sew?"

Student 1: "Maybe that would work."

Student 2: "All I know is that I spent all period ripping out this seam that was incorrect."

While instructor demonstrations were still important in Patternmaking II, the students were expected to build on the foundation they learned in Patternmaking I. Student visual learning occurred during instructor demonstrations, but more so with trial and error experimentations during the design phase, as well as during troubleshooting of garment construction and adjustments for fit. At the design critique, students presented their garment on their assigned form, rotating it and gesturing to

different areas of the garment when explaining their design process and when indicating what they would do differently.

Observations made of students during the two levels of patternmaking instruction were useful for a basic understanding of the opportunities students had for visual learning. It was also apparent that while some students demonstrated little difficulty with the visualizations or “mental images” required, there were others who were challenged or even frustrated at times. It is important for students to have this manual training in their education, but potential exists for enhancing the current approach to teaching 2D and 3D apparel design with computer-based technology.

Survey data was analyzed using SPSS statistical software to generate descriptives, frequencies, and tests of significance. Upon review of the data several findings were helpful in developing objectives and hypotheses for future research.

The majority of the sample, 92%, showed a high level of interest in advanced technology. A majority, 77%, were also in agreement that it would be helpful to evaluate flat patterns on a virtual model was still a majority, with more of the 200 level students showing an interest in virtual prototyping than 300 level students. Similarly it was found that the mean ASVT scores of students who agreed that it would be helpful to evaluate a virtual prototype were significantly higher ( $M=13.32$ ) than those who disagreed ( $M=10.71$ ). This supported research (Huk et al., 2003) from the field of engineering that found students with higher spatial visualization ability had a more positive attitude toward 3D simulations than students with lower spatial visualization abilities. This could indicate that the 200 level students are still fairly unsure about their 2D to 3D visualization skills and feel that a virtual prototype

would be useful, whereas the 300 level students have worked more with 2D/3D skills when producing physical prototypes on body forms.

The mean score on the ASVT across the sample as a whole was 12.71 (a range of 4 to 19 correct answers out of 20). The mean ASVT score for participants in Group 1 (200 level) was 11.68, and for Group 2 (300 level) it was 13.48. The difference in means between the scores in Group 1 and Group 2 was statistically significant, at .019. These findings supported ASVT research (Workman & Caldwell, 2007) which concluded that an the increased amount of training has a positive result on the spatial visualization of apparel design students, as the mean scores from the 300 level students ( $M=13.48$ ) were significantly higher than mean scores from the 200 level students ( $M=11.68$ ).

While the majority of the students had an interest in advanced technology, including virtual prototypes, and felt comfortable learning to use CAD, it was interesting to see the percentages drop slightly outside of the Patternmaking I students. What seems significant is that only half of the students in Patternmaking II indicated that they had used CAD for patternmaking, even though Patternmaking I is a prerequisite. It would seem that the brief introduction to apparel industry computer-aided patternmaking in Patternmaking I has too little impact on the students and was quickly forgotten. Including more exposure to 2D CAD patternmaking, even if through CAI simulations in Patternmaking I, and following up in Patternmaking II with interactive 2D to 3D CAD exercises, could engage students with more visual learning and potentially improve their spatial visualization skills.



The high percentage of surveyed students that were interested in advanced technology and that indicated virtual prototyping software provided a basis for research related to the comparison of student apparel specific spatial skills with the perceived ease of use and acceptance of 2D-to-3D CAD simulations in instruction of apparel design. In conclusion, the findings of this preliminary study were helpful for the planning of research related to student apparel specific spatial skills and perceptions of 2D-to-3D CAD simulations in instruction of apparel design.

### **Acquiring 2D/3D CAD for Research**

Based on the high interest in use of 3D virtually prototypes expressed by students surveyed in the pilot study, research was done on the availability of 2D/3D CAD software for use in research. While “off-the-shelf” CAD software exists and can be used for basic manipulation of 2D pattern piece geometries and 3D models, industry specific CAD has functionality designed specifically for patternmaking and often provides configurable 3D virtual models as well as libraries of simulated textile draping properties. Some of the leading apparel industry CAD vendors with 2D/3D CAD solutions included Gerber Technology, OptiTex, TukaTech and Assyst/Bullmer, Inc. Requests for purchase proposals of 2D and 3D software were made from these vendors.

I attended a Gerber Technology software user’s conference and participated in a virtual prototyping hands-on session. I also scheduled and attended a web demo by OptiTex in which basic use of the 2D and 3D CAD was shown. Promotional literature made available online by TukaTech, and Assyst/Bullmer was

reviewed and Assyst/Bullmer's 3D virtual prototyping solution was discussed during a brief update training. The basic 3D virtual prototyping workflow was found to be the same across each of the vendor's software solutions. However in some cases the 3D functionality is not integrated smoothly with the main 2D pattern design software. Therefore the user-interface had to be considered, as optimal use would be to have both the 2D pieces and 3D virtual prototype visible at the same time.

Another major consideration was the platform on which the software could run. Many of the 3D virtual prototyping solutions require advanced computing resources and may or may not run on both a PC and Mac platform. The preference of the faculty was for a CAD software that could be used in the college's Macintosh computer lab. Upon review of the vendor proposals and published customer testimonials, the textile and clothing program's faculty made a decision to purchase one license of OptiTex 2D and 3D software suite for testing and research purposes.

OptiTex software runs on the Windows platform and the license was installed on one of the department's Windows PC desktops. The software installation included some 2D pattern pieces and 3D virtual models for demonstration and training purposes. The OptiTex installation also included some "help" documentation, with more support and training documents provided online at their support web site (<http://help.optitex.com>). Using this documentation, I was able to learn the basics of both the 2D and 3D software solutions in order to provide feedback on the user-interface and give further demonstrations and to the textiles and clothing design faculty. The faculty made a recommendation to the computer advisory committee and the department purchased multiple licenses of OptiTex for

classroom use. With support from OptiTex, the College of Human Sciences IT staff tested and installed several of the licenses of OptiTex's 2D/3D CAD software.

### **Tutorial Development**

Permission to use the OptiTex software for research purposes was granted, as well as to use images and screenshots from the software (see Appendix D). The initially limited number of licenses installed to run the virtual prototyping software posed a problem in the method for exposing students to the software. However one case in the literature review used a "video mock-up" as exposure, along with a hands-on use of the actual system for comparison of the TAM module. That study (Venkatesh & Davis, 1996) was done in a time before widespread use of computer-aided instruction in the form of online tutorials. Current online "video" instruction often makes use of the Flash format that allows for "frames" with or pages including animations and interactivity (Boorady, 2005; Garcia, Quiros, Santos, Gonzalez & Fernanz, 2007).

Online support documentation provided by OptiTex for the 3D virtual prototyping software was used as a reference to develop the tutorial. However the installed software was a lower version than what was shown in the online documentation resulting in a need to reproduce many of the images and revise the workflow for use in the tutorial. The software installation did include some 2D pattern pieces for garments that are already prepared for simulation as a virtual prototype. For the purpose of the testing and for demonstration in the tutorial, I chose to use the provided 2D patterns for a simple dress that were not already prepared for 3D

simulation. The simplicity of the garment pieces allowed for a basic workflow and it was assumed that the students from both 200 and 300 level classes would be able to easily identify the patterns, which consisted of a front, back, sleeve and pocket. The default 3D model and fabric type provided with the OptiTex installation were used for the tutorial's simulation, although alternative options were shown in the tutorial for reference.

Using primarily the online documentation as a reference, as well as prior experience from participation in demonstrations and hands-on sessions of other 3D virtual prototyping software, I outlined a basic workflow. The steps were tested, revised and practiced, until it was possible to successfully generate a 3D virtual prototype using the 2D patterns for a short sleeved, t-shirt style dress.

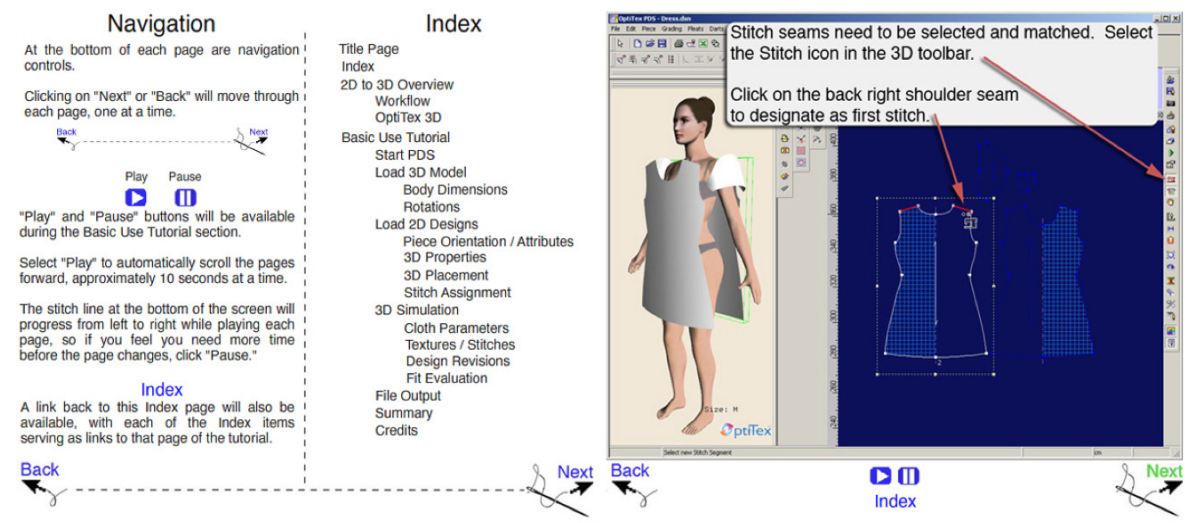
Snagit screen capture software by TechSmith was then used to take snapshots of each step in the process, with concentration on main menu selections and other tools used within the OptiTex software for generation of a virtual prototype. A total of 52 screen action shots were captured. These images were then edited using Adobe Photoshop CS2, for addition of text descriptions and arrows. Promotional images provided online by CAD vendors were used to create collage images for use on introductory and overview pages. A JPEG format snapshot of the 3D model clothed in the virtual prototype was also used as a visual in the layout of the pages. Other navigation related images created using Photoshop were stylized icons for "Back," "Next," "Play," and "Pause."

Using Adobe's Flash CS3 Professional software, a Flash project was created with an initial document size similar to that of a standard web site, or 800 pixels by

700 pixels. One advantage of Flash is that the tools allow for creating easily optimized vector art, but raster or bitmap images can be imported into the project's "library." Due to my familiarity with the raster image editing software Adobe Photoshop, as well as the need to use screen capture visuals, all of the images used in the tutorial were raster bitmaps imported into the Flash project's library. A total of 71 bitmap images were imported during the development of the tutorial. Other Flash library items that were created for use as interactive navigation tools were "buttons" and "symbols" which made use of Flash text tools as well as the imported navigation visuals. Flash "Actionscripts" were applied to these buttons and symbols with actions defined for navigation to appropriate frames in the tutorial's timeline.

Introductory frames including a title page, index and an overview of 3D virtual prototyping software. The Index had a two-column layout, with "Navigation" instructions in the left column and the "Index" in the right column. The "Index" was outlined in a "table of contents" fashion with 23 main sections of the tutorial listed as follows: Title Page; Index; 2D to 3D Overview; Workflow; OptiTex 3D; Basic Use Tutorial; Start PDS; Load 3D Model; Body Dimensions; Rotations; Load 2D Designs; Piece Orientation / Attributes; 3D Properties; 3D Placement; Stitch Assignment; 3D Simulation; Cloth Parameters; Textures / Stitches; Design Revisions; Fit Evaluation; File Output; Summary and Credits. Each section listed in the "Index" was a text format "symbol" with an Actionscript applied so that it would link to the appropriate section in the tutorial. All frames included navigation tools at the bottom of the page, allowing the participant to scroll forward or backward through the tutorial at their own pace, choose to play and pause the animation, or go directly back to the Index page

(see Figure 1 and Appendix E).



**Figure 1. Example of the Index page (left) and a frame from the tutorial (right).**

The bulk of the tutorial was made up of “Basic Use” highlights from a workflow typical of virtual prototyping software. The “Basic Use” section of the tutorial consisted of 40 frames comprised of screen captures with text descriptions and arrows provided for a general overview of menus, tools and steps required to generate a 3D virtual prototype garment. While not every step or function was described, the basics were covered, with assumptions made that a hands-on session participant could follow along with little assistance. For this section the participant was given the option to “play” or “pause” the action of the tutorial. If “Play” was selected each frame would stay on screen for approximately 10 seconds. A “stitch line” image was incorporated as an animated visual that progressed across the bottom of the screen from left to right as an indication of the time left on the display of the frame. At any time the participant could “Pause” the progression of

frames and chose to use either “Back” or “Next” to move backward or forward through the tutorial manually. A link back to the Index was also visible on each frame.

The initial steps in the “Basic Use” section of the tutorial demonstrated how to open the OptiTex software, followed by how to load and view the default “parametric\_woman” 3D model. Arrows were added to show the 3D toolbar available and to indicate icons to select to access a dialogue box allowing for manipulation of the 3D model’s body dimensions. Text instructions were also given for mouse clicks required to adjust rotations and zoom levels of the 3D model view.

The next section described work to be done on 2D patterns with a frame that showed menu selections and text that described how to open the dress garment’s 2D patterns. Initial steps to prepare the 2D patterns were shown in a series of four frames. Rotation of the sleeve piece 90 degrees using a “Rotate” icon and confirmation of the angle through a dialogue box was illustrated. Access to each pattern’s “Piece Attributes” was described, with steps illustrating the need to adjust “Quantity” of each piece, such as “2” for the sleeve. The process of creating mirrored halves for both the front and back patterns was illustrated.

For each pattern piece, 3D properties needed to be confirmed. These steps were shown in a series of six frames. First the menu selection necessary to view “3D Properties” was illustrated. The view of 3D Properties opened a “tabbed” window that shared the same space as the 3D model, with full view of the model slightly minimized during this work. Adjustments to the 3D properties for each pattern piece were illustrated, with the primary purpose being the definition of the

pattern's "Location." For example, the back pattern piece was given a Location defined as "Back" and the sleeve pattern piece's location was defined as "Right Arm." Arrows and text instructions illustrated the selection of each piece and described making the adjustments from drop-down menus and fields within the 3D Properties tab.

Once definition of 3D Properties was completed, instructions were given on how to maximize the view of the 3D model once more. Following frames began the illustration of 2D and 3D interaction, with the first step illustrating the use of the "Place Cloth" icon located in the 3D Toolbar. Instructions were given to rotate the view of the 3D model, which now included the 2D pieces placed around the body as per their defined location. An additional step illustrated the option to make minor adjustments to the location of the pieces, such as holding down the CTRL key and working in the 3D model view, clicking and holding to move the sleeve piece higher up on the arm.

One of the largest sections in the Basic Use tutorial was comprised of instructions for defining the stitch assignment. A series of 14 frames were used, with the first introducing the use of the "Stitch" icon selected from the 3D Toolbar. The frames that followed illustrated the process of using the "Stitch" tool to assign seams that should be stitched together to produce the 3D virtual prototype. For example, the back right shoulder seam and front right shoulder seam were selected for the first stitch assignment. Text descriptions and arrows were used in these frames to indicate correct points of selection and proper order of stitch assignment. The remaining frames in this section contained instructions for verifying the stitch



assignment with the pieces placed on the 3D model. Instructions were given to use icons in the 3D toolbar to “Clear Cloth” and “Place Cloth” and steps described the process of further manipulating the locations of the pieces on the 3D model.

Examples illustrated holding down the CTRL key to move the location of the sleeve further down on the arm of the 3D model so that stitch lines circumscribed the arm.

The next section, “3D Simulation,” gave instructions for completion of the 3D virtual prototype. A frame illustrating the use of the “Simulate Draping” icon in the 3D toolbar was the first in a series of six frames depicting various options available when working with the 3D virtual prototype. Descriptions were given to view once more the 3D Properties tab, where different fabric and stitch properties can be selected from libraries or adjusted manually. Two frames illustrated steps to apply textile print designs or textures to the cloth, and to change the color of stitches.

Another frame described steps for making design alterations to the 2D patterns such as dropping the neckline or lengthening the front and back piece before simulating the prototype once more. The last frame in the “3D Simulation” section illustrated use of the “Tension Map” icon in the 3D toolbar, which changes the view of the 3D virtual prototype to show color variation depicting a range of tension values.

Concluding frames in the “Basic Use” tutorial described steps to control the file output. Menu selections such as “File, Save As” were shown to store changes made to the 2D patterns. Arrows and text descriptions illustrated options to save the 3D model in a variety of formats compatible with third party 3D software applications, as well as saving a “snapshot” of the 3D virtual prototype in the JPEG image format.

A “Summary” frame reviewed the basic workflow followed in the tutorial and the last frame contained reference information in the form of “Credits.”

The completed Flash project tutorial consisted of 48 frames and was saved in the native Flash .fla format so that it could be further revised as necessary. For use in the instrument the project was also “published” as a “Shockwave” format .swf file with a corresponding HTML document that contained code necessary for viewing the tutorial with a web browser. An advantage of the Flash format is a relatively small file size, with the completed “tutorial.swf” stored as 3.7 MB. This file was uploaded to the WebCT server and a hyperlink was used to display the tutorial in the appropriate location in the survey instrument. The following section will describe in more the detail the development of the survey instrument.

### **Instrument**

In keeping with the study’s focus on technology, and to allow for online access of the Flash format tutorial, the chosen method of test instrument delivery was via the Internet. In an attempt to ensure security of copyrighted materials and confidentiality of the data, the instrument was developed in the form of an assessment within the WebCT environment, which required a login and password for access. A special purpose WebCT course named “TC Stewart 1,” was created upon consultation with an instructional support specialist. Working within the WebCT course environment allowed for convenient and secure delivery of the instrument to the chosen population, as students use WebCT for other coursework and can be easily enrolled with access to assessments controlled by selective release.

My role was designated as both course instructor and designer, which allows for full control and maintenance of the course content, such as student enrollment and assessment design. For development of the instrument, a question database first needed to be created. Once questions were ready in the database, they could be assigned to new assessments. An assessment in the format of a “survey” was used for this study, as the survey format allows for monitoring of student completion, but completed assessments remain confidential. Data from assessments can be downloaded in a comma separated value “report” format, with no student identifiers retained.

The assessment used as the main instrument of the study was named “2D/3D Research Survey” and consisted of 55 questions, also referred to as items (see Appendix F). Delivery of the assessment was controlled so that each item was delivered one at a time, with the participant having the option to not answer but still continue to the next question. To avoid any problems with browser pop-up blockers or multiple window confusion, the assessment was set to open in the same main browser window. The duration of the assessment was set to unlimited, so that a participant could pause or stop, and come back to finish it as needed. With the population sample to be made up of college students, basic familiarity with the functionality of WebCT and related assessments was assumed.

While I was able to “preview” the look of the course and assessment as a “demo student,” an informal peer review was also done. A graduate student and POS committee member were enrolled as students to the “TC Stewart 1” course and asked to access and provide feedback on the survey. During this peer review an

issue with screen resolution in relation to the size of the images was found. In order for the tutorial to be viewed completely on screen without having to scroll up or down the visuals and tutorial were resized to 600 pixel widths. It was also determined that the text of each item should stay within the same 600 pixel width, and this was controlled by use of HTML table formatting. Another suggestion was that more instructions should be given for each section and item.

Further testing of the instrument was done to ensure the compatibility of the instrument with commonly used browsers on both the PC and Macintosh platform. Development of the instrument was done on a Macintosh platform using Safari web browser, however when the assessment was previewed using Internet Explorer web browser on a PC platform there were issues with loading Flash format tutorial. As the PC Windows platform and Internet Explorer are most commonly used, this was a major concern ("Refsnes Data," 2007). Troubleshooting by myself and WebCT support specialists resolved the issue with the problem related to HTML coding required to embed the Flash format tutorial file. Other minor issues were resolved by further work and revision of the instrument. The following discussion will describe in more detail the measures and items included in the main survey instrument.

Sections or measures included in the "2D/3D Research Survey" were: demographics, computer self-efficacy, general spatial ability, apparel spatial visualization, 2D/3D virtual prototyping tutorial, perceived ease of use, perceived usefulness and comments. The first five items were short answer or multiple-choice format and covered demographic and background information: age, gender,

classification, course level and prior clothing construction experience. The next ten questions were items from a scale of computer self-efficacy.

Several scales of computer self-efficacy exist, however many use language specific to information technology, such as terms related computer hardware and programming. The scale which was found to be the most relevant and easiest to adapt for this study was the scale developed by Compeau and Higgins (1995). This scale was also used by researchers of technology acceptance (Venkatesh & Davis, 1996).

The Compeau and Higgins (1995) CSE scale asks the participant to imagine they were given a new software package for some aspect of their work and then makes statements about using the software under various conditions. The participant must rate the level of their confidence in their ability to use the software package under the stated condition, choosing from an 11 item Likert scale ranging from “Not at all confident” to “Totally confident.” For example, the condition statement used as a sample item was,

“I COULD COMPLETE MY WORK USING A SOFTWARE PACKAGE...  
...if there was someone giving me step by step instructions.

Other statements ranged from conditions such as using software with no guidance at all, using software with only online help as reference, and using software if someone demonstrated how to do it first. Many of these conditions are similar to what a student might experience when exposed to new software in a classroom format. Each condition was entered as a separate question, using multiple-choice format. The choices were 0 – 10, and represented the published

Likert scale, with 0 labeled as “Not, Not at all confident,” 5 labeled as “Yes, Moderately Confident,” and 10 labeled as “Yes, Totally Confident.” Only one choice was allowed.

For the test of general spatial ability, the review of literature provided several insights into different scales and formats used by researchers. While many of the tests use combinations of 2D and 3D visuals, requiring respondents to make mental rotations, a standard test found to be most relevant to this study was the Surface Development test (VZ-3) from the Kit of Factor References Cognitive tests (Ekstrom et al., 1976). The VZ-3 shows a 2D figure that can be folded to make the given 3D shape. Mental folding and rotations are required to visualize the matching fold and cut lines labeled on both the 2D and 3D images. This 2D to 3D process is similar to the visual process used in patternmaking and garment assembly associated with apparel design. The VZ-3 tests general spatial ability and was found to correlate significantly with the ASVT in research done by Workman and Zhang (1999).

The Surface Development Test is made of two parts, each containing six items. For each item there is a 2D figure and 3D shape, each sharing five or more labeled edges (numbers on the flat figure and letters on the 3D shape). One shared surface on the 2D figure and the 3D shape is labeled with an “X” to use as a point of reference. For each item the respondent must correctly match five numbered lines from the 2D figure to 5 lettered edges on the 3D shape, therefore when both parts of the test are used, the total number of correct selections would be 60. In an effort to reduce some of the time and frustration that might be encountered with this kind of test, I chose to include only the first part.

Permission was granted by the Educational Testing Service to use the Surface Development Test (see Appendix B). Items 16 – 21 in the online test instrument included the six spatial ability tests from Part 1 of the Surface Development Test (VZ-3). Using an image editing software I retrieved the illustrations from the PDF format file provided by ETS, and then cropped and saved each as a JPEG image format, 600 pixels wide. The 600 pixel width of the image was determined after initial pilot testing or “preview” of the assessment within the WebCT environment. Larger image dimensions resulted in the user having to do too much scrolling left and right or up and down to view the complete image. All images from Part 1, as well as the Sample item, were uploaded to the WebCT server and linked to from the appropriate assessment questions using hypertext markup language (HTML). Matching Pairs question format was selected, with pairs numbered 1 – 5, each with selections available from a range of letters A – I, as appropriate for each visual. A letter could be selected for more than one pair as needed.

Only one test existed to measure domain specific spatial ability related to apparel design. Workman et al. developed the Apparel Spatial Visualization Test in 1997. The Apparel Spatial Visualization Test (ASVT) consists of 20 sets of pattern pieces and groups of garment sketches. The subject must determine which garment sketch (out of a group of five) can be constructed from the set of pattern pieces shown. Validity of the test has been conducted by comparing scores of subjects from the ASVT with scores on three tests of general spatial abilities: the DAT:SR, the Surface Development Test, and the Paper Folding Test (Workman & Caldwell,

2007). The 20 item ASVT was used with permission by the authors (see Appendix A). Again I retrieved the illustrations from a PDF format file provided by the authors, cropping and saving each as a JPEG image format, 600 pixels wide. All images were uploaded to the WebCT server and linked to from the appropriate assessment questions using hypertext markup language (HTML). These questions were positioned as items 22 – 41 in the assessment. Multiple choice question format was selected, with the choices represented by letters A - E as used in the labeled garment sketches. Only one choice was allowed.

The last main section of the instrument included the 3D virtual prototyping tutorial followed by items intended to measure user acceptance of the software as presented. The two technology acceptance constructs of interest to this study were perceived ease of use (EOU) and perceived usefulness (U). Items to measure EOU and U were adapted from the scale developed by Davis in 1989. Both EOU and U had six items, with each item comprised of a statement and a seven point Likert scale of likelihood. Examples of statements of ease of use were “Learning to operate 3D virtual prototyping software would be easy for me” and “I would find it easy to get 3D virtual prototyping software to do what I want it to do.” Examples of statements of usefulness were “Using 3D virtual prototyping software in my work would increase my productivity” and “Using 3D virtual prototyping software would make it easier to do my work.” The items were in multiple-choice format, with 1 labeled as “Extremely Unlikely,” 4 labeled as “Neither” and 7 labeled as “Extremely Likely.” Only one choice was allowed. The Flash format tutorial was embedded into HTML of the first



EOU item, with instructions indicating that the respondent should navigate the tutorial before continuing with items 42 – 53.

To conclude the main survey instrument item #54 asked respondents to write comments about their general perception of 3D virtual prototyping software and its possible use in instruction of apparel design. The format of this item was as a “paragraph question” with a text field available for a type written answer. The purpose of asking an open-ended question of this kind was to measure overall perceptions and it was assumed that comments would be generally positive or negative in nature. The last item of the survey was in short answer text field format, requesting that any respondent with intentions to participate in a separate hands-on session enter the first four digits of their university ID number. A disclaimer stated that the four digits would only be used for purpose of data collection and analysis and would not be retained with the data or used for identification.

A second 19 item survey assessment was created named “Hands-on Session Follow-Up.” Access to this assessment was controlled by WebCT’s selective release functionality so that it only became visible to respondents upon completion of the main “2D/3D Research Survey” assessment. A description label for this assessment was made instructing respondents to complete this follow-up survey only upon participation in a hands-on session. The first item in the “Hands-on Session Follow-up” survey again asked the respondent to enter the first four digits of their university ID number, with the same confidentiality disclaimer. Items 2 – 13 were the same as items 42 – 53 in the main survey, with the Flash tutorial once again embedded in the HTML of the first EOU item.

The concluding items 14 – 19 were a combination of multiple choice and paragraph formats intended to gather general opinions and comments related to perceptions of 3D virtual prototyping software and its possible use in instruction of apparel design. For example, items 15 and 17 were “yes/no” questions worded “Do you feel 3D virtual prototyping software would be useful for instruction of apparel patternmaking / design concepts?” and “Do you feel that tutorials such as the one seen in this survey would be useful for learning 3D virtual prototyping software?” respectively. Item #16 was a multiple choice question, “At which course level(s) do you feel working with 3D virtual prototyping software would be appropriate?” with multiple selections allowed from a listing of course levels ranging from 200 level to 500 level. Items #19 and #20 were both in paragraph format with text fields allowing for type written answers in response to requests for comments or description related to how the 3D virtual prototyping software might be used in coursework and any changes in perception after participating in the hands-on session.

### **Research Design**

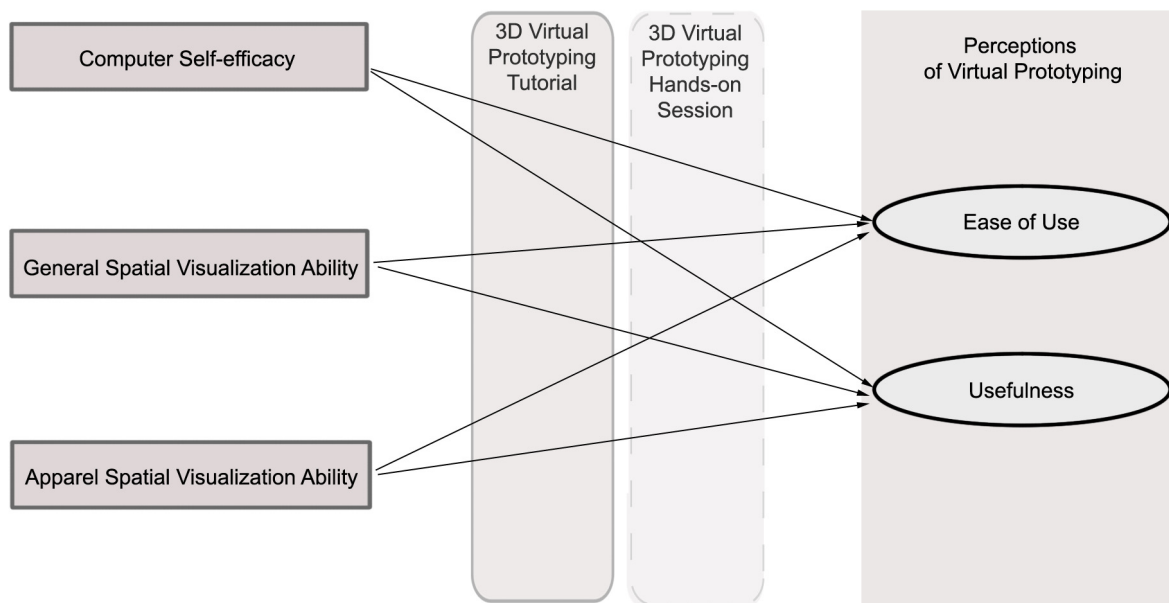
Research from a review of literature showed that exposure to 3D modeling software or CAI simulations may not have a direct impact on improvement on general spatial visualization abilities, as much as domain specific training does. Therefore a pre-test post-test design was not necessary, as the goal was to test the student’s perceptions toward use of 3D virtual prototype simulation during instruction compared to their level of spatial ability.

Following the pilot study, I decided that the sample population would be drawn from students enrolled at the 200 level flat pattern course or advanced design courses at the 300 level or higher. While no hypothesis related to differences between course level would be tested, drawing from this sample population would make it possible to examine descriptive statistics, comparing results by course level. Information of this kind could be useful in apparel design curriculum development, indicating at what course level the introduction of advanced CAD would be most effective.

The pilot study, as well as findings in the literature review, inspired the use of three independent variables: computer self-efficacy, general spatial ability and apparel specific visualization ability. As computer self-efficacy was found to be an antecedent of perceived ease of use, the extended technology acceptance model developed by Venkatesh and Davis (1996) was used as reference when developing the visual representation of this research design (see Figure 2). Their study also inspired the use of a tutorial as the stimulus or mode of exposure to the 3D virtual prototyping software, and the use of a “hands-on session.”

Eight null hypotheses were proposed and were to be statistically tested using SPSS software. The hypotheses were formulated based on the independent variables, testing each variable for changes in the perceived ease of use and perceived usefulness of the software. Also, one hypothesis was used to test if there would be a difference between the perceptions of ease of use and usefulness before and after direct exposure to the software with the hands-on session.

Each volunteer completed the main test instrument, with a smaller group choosing to participate in the hands-on session. All participants were exposed to the 3D virtual prototyping software by an online tutorial that described and gave examples of a workflow for generating a virtual prototype of a basic t-shirt dress. The hands-on session participants referred to the same tutorial during actual use of the software, with participants following the tutorial's workflow to generate the example virtual prototype.



**Figure 2. Research design adapted from an extension of the TAM.**

### **Data Collection and Analysis**

The study was reviewed by the Institutional Review Board Chair and declared exempt from requirements of human subjects protections (see Appendix C). Class enrollment lists were acquired from the instructors of 200, 300 and 400 level apparel

design courses, and these were used for enrolling the population in the WebCT course “TC Stewart 1.” Following enrollment of the population, a recruitment email was sent announcing the opportunity to participate in the study (see Appendix G). Volunteers were encouraged to log into WebCT and enter the “TC Stewart 1” course where the home page was a copy of the recruitment letter and a link to the “2D / 3D Research Survey” was visible. By accessing and beginning the “2D / 3D Research Survey” assessment the volunteers were giving their consent to participate in the research. The “2D / 3D Research Survey” assessment remained accessible to the entire population for one full week.

Volunteers who completed the “2D / 3D Research Survey” and who also expressed interest in participating in a hands-on session were asked to email the researcher with their availability or preference to attend one of ten arranged meeting times. The hands-on sessions schedule offered morning and afternoon times designed to avoid conflict with class meeting times. Due to the limited number of seats available, assignment to sessions was made on a first come first serve basis. Confirmation of the session to attend was made with the participant via email discussion. The “Hands-on Session Follow-up” assessment was selectively released to all participants who both completed the main survey and confirmed interest in attending a hands-on session.

Hands-on sessions were held in the college’s Macintosh computer lab, with two iMacs near the back of the room reserved for this purpose. A total of 10 hands-on sessions were held, with a maximum of two students participating at one time, resulting in a total of 15 participants. Duration of these hands-on sessions was

dependent on the participant's progress through the tutorial, however most sessions lasted 30 – 40 minutes. I was present during the hands-on sessions and gave initial instructions to participants for logging into WebCT and accessing the “TC Stewart 1” course and “Hands-on Session Follow-up” assessment. I demonstrated manipulation of the web browser window size so that it was approximately the size of the tutorial and no larger. The participants were then instructed to move the browser window to the right side of the desktop area. In this way both the tutorial and 3D virtual prototyping software could be on screen at the same time (see Figure 3).



**Figure 3. Volunteers participating in a hands-on session.**

Participants were instructed to begin the tutorial and to use the 3D virtual prototyping software as they followed along with the tutorial's steps on their own. I was available during the sessions to answer questions and to give brief explanations about the process when requested. I took observation field notes during the hands-on sessions for use as insights for discussion and in future recommendations.

Confidential data sets were downloaded from WebCT in a comma separated value file format. In preparation for analysis the data was reviewed and coded using Excel spreadsheet software's "Find and Replace" functionality. Data from both assessments were combined into one file, with the variable named appropriately to differentiate between pre and post hands-on session. Out of the 15 participants from the hands-on sessions, three of the data sets were dismissed due to inability to match ID numbers between the surveys.

Data analysis was performed using SPSS statistical software with the data transferred into the SPSS data table format by copy and pasting values from the Excel spreadsheet. Descriptive reports were generated on the data as a whole, followed by tests for reliability. Reliability of greater than .09 was found for items related to computer self-efficacy, perceived ease of use, perceived usefulness constructs. Composite variables were created for each of those constructs for later use in Independent Samples T-Tests, One-way ANOVAs and Paired Sample T-Tests. An alpha level of .05 was used for all statistical tests.

High and low levels of computer self-efficacy and general spatial ability were determined by a median split, with recoded variables computed. Due to a large number of scores on the apparel spatial visualization ability falling at the median, a

recoded variable was computed for levels of high, average and low. Participant comments collected by open-ended survey items were compiled and coded as either “positive” or “negative.”

### **Limitations**

Due to the online delivery of the instrument the conditions were not completely controlled. It is possible that groups of students may have taken the survey together, discussing their answers for the spatial ability tests. Another possibility is that all participants may not have fully navigated the tutorial or even realized there was more to it than the title page. The tutorial was written for a version of the 3D virtual prototyping software that is now lower than what is installed; therefore it will need to be redesigned for use in coursework. The sample was made from a convenient population and therefore results shouldn't be generalized to describe textiles and clothing students as a whole.



## **CHAPTER 4: RESULTS AND DISCUSSION**

### **Introduction**

In this chapter I analyze and discuss the findings from all sections of the test instrument. Initial findings will be explained using descriptive statistics. Within this general description, some comparisons will be made to the pilot study sample. Findings related to the objectives of the study will be discussed with brief statements of support or non-support for each hypotheses and discussion of each. Reflection on observations made during the hands-on sessions will also be included. I will conclude the chapter with a summary and examples of the opinions and comments requested of the focus group participants.

### **Description of the sample**

The number of students recruited for the research study and enrolled in the WebCT course was 74, with an actual sample size of 40 participants. The difference in size is due to the method of recruitment and delivery. The population was made aware of the study by use of a recruitment email (see Appendix G). While they were encouraged to access the online instrument and participate on their own time, this resulted in fewer participants than the face-to-face “paper and pencil” delivery of the pilot study’s instrument. A subset of the sample became a focus group, made up of 15 hands-on session participants.

All participants were students enrolled in the textiles and clothing program of a major Midwestern university in the fall of 2007. In the resulting sample all

participants were female with the average age of 21 reported<sup>1</sup>. Students classified as seniors made up 42.5% of the sample, with the next largest group sophomores at 37.5%, followed by juniors at 15% and 5% made up by graduate students. The sample consisted of 60% students enrolled in the 200 level and 40% enrolled in 300 or higher level classes. Students at the 200 level had completed or were completing the Patternmaking I course (beginning flat pattern). Students at the 300 or higher level had completed or were completing the Patternmaking II course (draping) and at least one other 300 or 400 level design course (advanced design concepts in Creative Design Processes, and/or Senior Design Studio, or computer-aided design in Computer Integrated Textile and Fashion Design).

Basic population demographics were similar to those in the pilot study sample, which also had an average age of 21 and a high percentage of female participants. Another similarity was that 63% in both samples indicated they had experience with clothing construction prior to their undergraduate study. The students in both studies were enrolled from a similar range of 200 – 400 level courses. An exception in the present study was that students registered for Patternmaking II were not explicitly recruited; rather students from advanced design classes for which Patternmaking II is a prerequisite were recruited. This was done for the purpose of having a slightly more defined difference between the introductory level group and the advanced level group.

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<sup>1</sup> Gender differences were not a focus of this study

One difference between the pilot study and present study was the sample size. The pilot study was 82% larger in size. This size difference was likely due to the delivery of the instrument. While online distribution of the study for this research was convenient for access to the instrument and tutorial, it was ultimately less effective for participant recruitment. The face-to-face delivery of the pilot study printed survey to students in a classroom setting provided a more focused and monitored environment.

Another difference in the sample of the pilot study and the present research was in the percentage of 200 level students compared to 300 or higher level students. In the pilot study, a larger percentage of the sample (57%) was made up of 300 or higher level students, compared to 40% in the present study. Potentially project loads and time commitments were heavier for the 300 level or higher students later in the semester than they were in the pilot study, which was conducted a few weeks earlier in the semester. The higher percentage of 200 level participants may also have occurred because the instructors encouraged participation with earned extra credit.

## **Objectives**

The following section will discuss in more detail the findings related to the study's five objectives.

The first objective was to assess the computer self-efficacy (CSE) of apparel design students. The main "2D / 3D Research Survey" instrument contained ten items to measure computer self-efficacy as developed by Compeau and Higgins

(1995). Respondents were asked to read a condition statement about using a software package they had never used before, and then select a confidence rating, from an 11 point scale, based on their perceived ability to complete work using the software.

The ten items in the scale ranged in perceived amount of assistance required by the respondent, increasing from no assistance at all, to fairly high assistance, such as having someone show how to use the software first. The ten items were found to have a reliability coefficient greater than .09 (.91). A composite computer self-efficacy variable (COMCSE) was computed, with mean for the sample equal to 6.34 ( $SD = 1.56$ ), slightly higher than “Moderately Confident” (see Table 1).

**Table 1. Computer Self-efficacy**

Not at all confident				Moderately Confident				Totally Confident		
0	1	2	3	4	5	6	7	8	9	10
<b>I COULD COMPLETE MY WORK USING THE SOFTWARE PACKAGE...</b>										<b>M</b>
...if there was no one around to tell me what to do as I go.										4.20
...if I had never used a package like it before.										3.22
...if I had only the software manuals for reference.										5.58
...if I had seen someone else using it before trying it myself.										5.95
...if I could call someone for help if I got stuck.										6.93
...if someone else had helped me get started.										7.18
...if I had a lot of time to complete the job for which the software was provided.										7.65
...if I had just the built-in or online help facility for assistance.										6.02
...if someone showed me how to do it first.										8.68
...if I had used similar packages before this one to do the same job.										8.05
COMCSE										6.43

The mean of the COMCSE was comparable to a composite computer self-efficacy mean ( $M = 6.87$ ) reported using the same scale in research by Downey and McMurtrey (2006) on a sample of students with a similar age ( $M = 22$ ).

For items measuring CSE, the amount of assistance using the software increased with each statement. As the level assistance increased the mean level of confidence also increased, with two exceptions. The level of confidence ( $M = 4.20$ ,  $SD = 2.48$ ) for the first item's statement of least assistance, "no one around to tell me what to do as I go," was slightly higher than the second item. The second statement "I could complete my work using the software package if I had never used a package like it before" was found to have the lowest confidence rating out of all ten items ( $M = 3.22$ ,  $SD = 2.03$ ). These findings indicate that while the sample had overall moderate computer self-efficacy they were least confident in their skills if they had to use a new software package with little assistance.

The other exception was found for the eighth item in the scale, "if I had just the built-in or online help facility for assistance." The mean level of confidence on this condition ( $M = 6.02$ ,  $SD = 2.03$ ) was just slightly higher than "Moderately Confident" and lower than the means of the two items prior. This exception is relevant as this item is one of only a few items in the scale that refer to a condition in which there is not "someone" else to offer assistance in some form. It may be possible that the respondents were not familiar with what "built-in" or "online help facility" meant, or had prior experiences in which using that kind of electronic resource was not helpful. It could also show that students still have only slightly moderate confidence in their skills if they had to figure out how to use software on their own, without face-to-face instruction.

The composite mean for computer self-efficacy of the 300 level or higher students ( $M = 6.58$ ,  $SD = 1.87$ ) was higher than the composite mean for 200 level

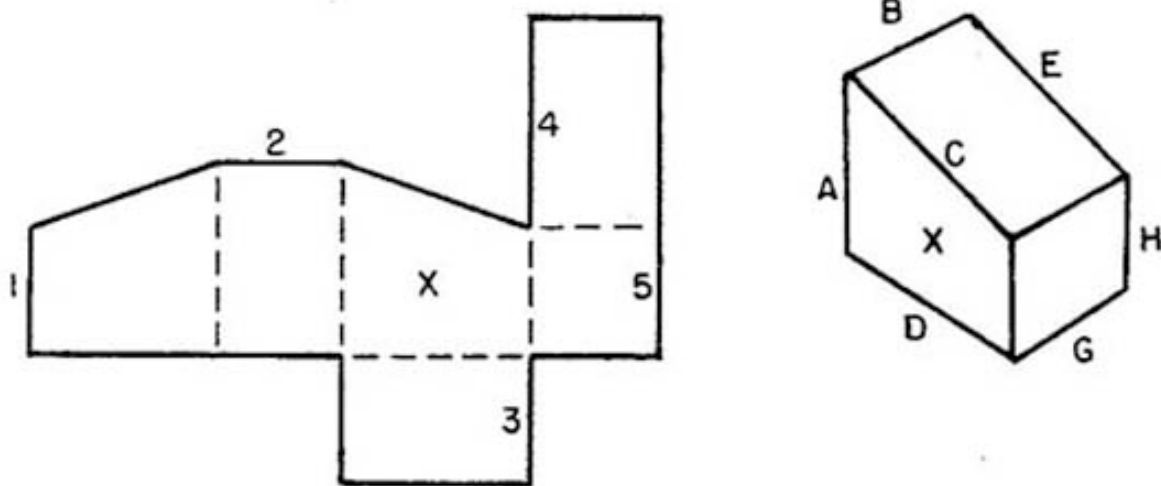
students ( $M = 6.18$ ,  $SD = 1.35$ ) although not significantly higher,  $t(38) = -.775$ ,  $p = .443$ . Many of the 300 level or higher students had more exposure to computer software and therefore may have increased the mean confidence if they had successfully completed the 300 level Computer Integrated Textile and Fashion Design course. Within the course level groups, individual means for each CSE items, for most cases, had higher confidence in the 300 level or higher group. One exception was on the fourth item, “if I had seen someone else using it before trying it myself.” On this item the 200 level group had higher confidence ( $M = 6.17$ ,  $SD = 2.05$ ) than the 300 level or higher group ( $M = 5.62$ ,  $SD = 2.96$ ). Potentially this could be due to the slight difference in mean age, with the slightly younger 200 level students ( $M = 20$ ) still building their confidence and knowledge by observing others first.

For later comparison of CSE with perceived ease of use and perceived usefulness, the composite CSE was also recoded into a split variable, using the median of 6.65. The median split resulted in two groups, 50% of which were considered as having “low” CSE, and 50% of which were considered as having “high” CSE. However a more descriptive statistic is seen when splitting by a central “moderately confident” rating of 4.5, which finds the percentage of students with “low” CSE ( $M = 3.92$ ) as only 17.5% and those with “high” CSE ( $M = 6.85$ ) as 82.3%.

A large percentage of “high” CSE across the sample is supported by a study describing the “Net Generation.” Oblinger and Oblinger (2005) reported that students of the sample’s generation were born at the same time as the PC, with 20% using computers by the time they were 5 years old. Long exposure to computers

and learning new software packages could explain the sample's overall high level of computer self-efficacy.

The second objective of the study was to assess general and domain specific spatial visualization skills of textiles and clothing apparel design students. Items used to measure general spatial ability were from Part 1 of the Surface Development Test (VZ-3) containing six items. For each item there was a 2D figure and 3D shape, each sharing five or more labeled edges, numbers on the flat figure and letters on the 3D shape (see Figure 4).



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**Figure 4. Practice problem from Surface Development Test VZ-3, Part 1.**

One shared surface on the 2D figure and the 3D shape is labeled with an “X” to use as a point of reference. For each item the respondent was to match five numbered lines from the 2D figure to 5 lettered edges on the 3D shape. A Matching Pairs question format was used, with pairs numbered 1 – 5, to be matched with

selections available from a range of letters A – I, as appropriate for each visual. A letter could be selected for more than one pair as needed.

For each item of general spatial ability, five answers were scored which could result in a total perfect score of 30. Other studies that used the VZ-3 implemented both parts, for a total score of 60. Ekstrom et al. (1976) reported a mean score for both parts as 43.6 for college students (72.6% correct) and 36.8 by army enlistees (61% correct). The average score on the VZ-3 in a study by Workman and Zhang (1999) was 34.36 equaling 57% of the matched selections correct on average. That study also reported the mean scores of their sample's CAD group ( $M = 43.6$ ) or 72% correct on average, and manual patternmaking group ( $M = 41$ ), or 68% correct on average. Those scores compared more closely to the scores reported by Ekstrom et al. (1976). The mean general spatial ability score of the present study's sample was 21.5 ( $SD = 7.92$ ), ranging from a low score of 4 to a high score of 30. This mean score compares to those found in other samples when viewed by percentage of correct answers, 72%. Within the sample, 57% scored slightly above the mean, with the remaining 43% scoring 21 and lower. Five participants scored a perfect score of 30.

The six items measuring general spatial ability increased in difficulty related to the number of folded edges and subsequent mental folding or rotations required. Out of the six items, the first item, and therefore the most simple, had the highest percentage (78%) of correct answers. This item showed a triangular 3D shape having six edges labeled A – F, as well as the corresponding unfolded figure showing three dashed fold lines and five numbered edges, 1 – 5. As the remaining



items increased in difficulty, the percentage correct decreased, with the fourth and fifth items sharing the lowest percentage of correct answers (64%). One respondent who had scored 99% correct on the first three items simply stopped after the third item, not choosing to answer the remaining items. From the slightly above average percentage of correct answers it could be hypothesized that the items measuring general spatial ability were challenging. As one participant observed during the hands-on session, “those folding boxes about killed me.”

The mean general spatial ability score for the 200 level group was 20.04 ( $SD = 8.58$ ), and 23.69 ( $SD = 6.49$ ) for the 300 level or higher group. The difference in mean scores of the 200 level group and 300 level or higher group was not statistically significant,  $t(38) = -1.44$ ,  $p = .157$ . In the 300 level or higher group 69% scored above the sample’s mean. In the 200 level group a lower percentage (50%) scored above the sample’s mean. The higher spatial ability in the 300 level or higher group supports studies finding increased training improves spatial ability (Olkun, 2003; Scribner & Anderson, 2005; Workman & Caldwell & Kallal, 2007).

For later comparisons, a median (23.5) split was used to create groups of high and low general spatial ability. This split was primarily used to test the hypothesis that differences in perceptions of ease of use and usefulness exist in individuals with low or high spatial ability. However the split was also used to test for differences in the mean scores of domain specific apparel spatial visualization ability that will be described in the following discussion.

To measure domain specific spatial visualization ability 20 items from the Apparel Spatial Visualization Test (ASVT) were used. The ASVT consists of 20 sets

of pattern pieces and corresponding groups of labeled garment sketches. The test subject must determine which garment sketch (out of a group of five) can be constructed from the set of pattern pieces shown. Multiple choice question format was used, with the choices represented by letters A - E (as used in the labeled garment sketches).

The mean ASVT score of pilot study's sample was 12.71 ( $SD = 3.26$ ), ranging from a low score of 4 to a high score of 19. The mean ASVT score of the present study's sample was slightly higher at 13.15 ( $SD = 3.07$ ), ranging from 5 to 19. This difference may be due to increased focus on spatial visualization within the past year's apparel design curriculum. A Basic Design Concepts Review course was introduced with one of the objectives listed as skill assessment related to 2-dimensional and 3-dimensional visualization. Another possibility for the increase is that a small percentage of the sample may have participated in the pilot study and therefore improved upon second attempt of the ASVT, though they were never shown the correct answers.

For each item only one answer is correct, with a perfect score of 20. Similar to the Surface Development Test, the items typically increased in difficulty depending on the number of pattern pieces in each set, from two to seven pieces. In both the pilot study and the present study, the percentage of correct scores per set varied, not necessarily dependent on the number of pattern pieces. For example, set #13, which consisted of five pattern pieces that could be used to construct a long sleeved, raised neckline shirtdress style garment, had one of the highest percentage of correct answers in both studies, with 97.5% answering that item correctly in the

pilot study and 95% in the present study. One possible reason for this item being somewhat “easy” could be the fact that only one of the garment sketches shows pleat details at the shoulder, which are clearly visible at the shoulder seam on the front bodice pattern piece. Other seemingly easily identified sets, with percentages of correct answers over 90% for both studies were; set #3 (three pattern pieces for a short sleeve v-neck top), set #7 (four pattern pieces for a scoop neck tank top), and set #11 (five pattern pieces for a short sleeve princess seam jacket).

Another similarity between the pilot study and the present study on the ASVT was the item that had the lowest percentage of correct answers. The correct answer for set #5 was only selected by 2% of the sample in both studies. This set consisted of only three pattern pieces that could be used to construct a simple long sleeved, crew neck top. The incorrect garment sketch picked by the majority in both cases was a simple short-sleeved crew neck style garment. While this set should be one of the least difficult, it seems that the length of the sleeve created some confusion. However it could be argued that the sleeve on the garment sketch of the item picked incorrectly by the majority does appear to have some length to it in the guise of a hem that is folded or rolled up.

Comparisons of ASVT scores between course levels were performed in both studies. The mean ASVT score of the pilot study’s 200 level group was 11.68 ( $SD = 3.02$ ) and the mean for the 300 level group was 13.48 ( $SD = 3.26$ ). In the pilot study the difference between the mean scores of ASVT between the two levels was significant,  $t(71) = -2.40$ ,  $p = .019$ . For the present study, the mean ASVT scores were slightly higher for each group, with 12.5 ( $SD = 3.36$ ) found at the 200 level and

14.13 ( $SD = 2.34$ ) for the 300 level or higher group. While the difference in means between these two groups was not found to be statistically significant ( $t[38] = -1.68$ ,  $p = .101$ ) the higher mean score of the 300 level or higher students supports research showing that spatial ability increases with amount of training (Olkun, 2003; Scribner & Anderson, 2005; Workman & Caldwell & Kallal, 2007).

A high and low ability ASVT group could not easily be split by the median (13) since there were 10 respondents who scored at the median. In this case, the scores were split into high, medium and low. This put the mean ASVT score for the high group at 15.88, the mean ASVT score for the medium group at 13 and the mean ASVT score for the low group at 9.69. Comparisons for the hypotheses testing will be made across the three groups with a One-way ANOVA, as well as between the high and low groups with Independent Samples T-Tests.

When testing for differences in mean ASVT scores between individuals with high general spatial ability and low general spatial ability, individuals with high general spatial ability did have a significantly higher mean score on the ASVT ( $M = 14.5$ ,  $SD = 2.89$ ) than individuals with low general spatial ability ( $M = 11.8$ ,  $SD = 2.67$ ),  $t(38) = 3.07$ ,  $p = .004$ . This finding is supported by the research of Workman and Zhang (1999), who found that high scores on the surface development test correlated with high scores on the ASVT.

The third objective was to develop a 2D/3D CAD virtual prototyping software tutorial. For this objective no items were specifically assigned for statistical analysis. However, one open-ended item on the “Hands-on Follow-up Survey” did ask the respondents “Do you feel that tutorials such as the one seen in this survey would be

useful for learning 3D virtual prototyping software?” Out of the 12 hands-on participants, the response for this question was 100% positive. A few participants offered written comments that mentioned the tutorial. Only one respondent stated that the tutorial was confusing,

“The tutorial seemed complicated. I felt like there were a few things that weren’t explained. For example, what did the degrees mean? Why were some of the pieces put at 10 degrees, but others were at 50 degrees. And when clicking to connect the seams, how did the program know which ones were pairs? It seemed like the tutorial was saying, “Just keep clicking on stuff! It’ll work, trust me!” I was confused.”

As the tutorial was intended for a general introduction to the 3D virtual prototyping workflow, with steps outlined only for basic use, it was not feasible to add details and explanations for every step. For use in the classroom, a tutorial of this kind might be followed up with more detailed instructor demonstrations or lab activities that allowed students to experiment with the various settings. Other participants commented that tutorials of this kind could be useful in a classroom setting, “I think a tutorial would be necessary for at least the first couple of sessions in order to fully understand all of the complex ways to use this program.”

The fourth objective was to assess student perceptions of ease of use and usefulness of 3D virtual prototyping software after exposure to the tutorial. Items to measure perceived ease of use (EOU) and perceived usefulness (U) were adapted from the scale developed by Davis in 1989. Both EOU and U had six items, with each item comprised of a statement and a seven point Likert scale of likelihood. The items were in multiple choice format, with 1 labeled as “Extremely Unlikely,” 4 labeled as “Neither” and 7 labeled as “Extremely Likely.” Only one choice was

allowed. All participants were asked to rate the perceived ease of use and usefulness of 3D virtual prototype simulations after navigating the tutorial in the main “2D/3D Research Survey.”

The six items measuring ease of use had a reliability coefficient of .88. A composite ease of use variable (COMPEOU) was recoded. The mean COMPEOU ( $M = 4.92$ ,  $SD = .962$ ) for the whole sample after viewing the tutorial fell closer on the scale to “Slightly Likely” than “Neither.” The ease of use item rated the most strongly as “Slightly Likely” was “It would be easy for me to become skillful at using 3D virtual prototype simulations.” The item rated the most strongly as “Neither” was “My interaction with 3D virtual prototyping simulations would be clear and understandable.” These findings indicate that the exposure by tutorial only may have made 3D virtual prototyping appear slightly easy to use although there was still some confusion or unanswered questions remaining.

By course level, the highest mean COMPEOU ( $M = 4.94$ ,  $SD = 1.08$ ) was found in the 300 level or higher group although it was not significantly higher than the 200 level group’s mean COMPEOU ( $M = 4.90$ ,  $SD = .901$ ),  $t(38) = -.121$ ,  $p = .904$ . Within the six EOU items there were no significant differences between the two course levels.

Similar to perceived ease of use, the six items measuring perceived usefulness had a reliability coefficient of .92. A composite variable was computed (COMPEOU) with a mean of 5.50 ( $SD = 1.06$ ), “Slightly Likely.” Out of the six items measuring perceived usefulness, the item that was rated the closest to “Quite Likely” ( $M = 5.82$ ,  $SD = 1.28$ ) was “I would find 3D virtual prototype simulations useful in my

work.” While no significant differences were found among the six items measuring perceived usefulness by course level, that same item referring to usefulness for work had a higher mean ( $M = 6.06$ ,  $SD = 1.18$ ) in the 300 level or higher group than the 200 level group. Potentially, the 300 level or higher group contained students who had completed internships and therefore were more impressed by the 3D virtual prototyping related to skills valuable for employment.

Several comments made after viewing the tutorial indicated that students felt that skills related to 3D virtual prototype simulations would be beneficial to have for their future careers. One participant stated, “It seems like something that would be extremely useful in the industry, especially if the person using it knew how to use it really well.” Another commented, “I think this would be very helpful and useful for future careers !” Other comments made after exposure to the tutorial indicate that students think 3D virtual prototyping would also be useful in coursework. One participant stated, “I think 3D virtual prototyping software could be extremely useful in that it could quickly demonstrate pattern shape and fit principles to students, without the need for so much time-consuming sample construction.”

While not specifically an objective of this study, the influence of perceived ease of use on perceived usefulness was tested. As found in the literature review, perceived ease of use can have an influence on perceived usefulness (Davis, 1989; Venkatesh & Davis, 1996). When the perceived ease of use was split by the “Slightly Likely” rating of 5, it individuals who perceived the software to be easy to use ( $M = 6.05$ ,  $SD .78$ ) also perceived the usefulness as “Quite Likely” ( $M = 5.75$ ,  $SD = .91$ ). This was significantly higher than the perceived usefulness ( $M = 4.77$ ,

$SD = .95$ ) found by individuals who perceived the software less easy of use,  $t(38) = 4.68$ ,  $p = .000$ . Therefore the ease of use of 3D virtual prototyping software has influence on its perceptions of usefulness, as individuals who found it easy to use also found it more useful. This should be taken into consideration when introducing the software to a classroom setting, to enhance ease of use. This could include offering generous assistance during lab activities, engaging demonstrations and tutorials.

The fifth objective was to assess student perceptions of ease of use and usefulness of 3D virtual prototyping after exposure to the tutorial followed by hands-on interaction with the software. Participants who completed the “2D/3D Research Survey” were given the opportunity to sign-up to participate in a hands-on session. Ten hands-on sessions were held over the span of three days. One to two students participated in each of the hands-on sessions for a total of 15 participants. Each participant was instructed to access the online “Hands-on Session Follow-up” assessment that contained the same tutorial as viewed in the main instrument. This “hands-on session” differed from the regular “tutorial only” session in that the students actually were able to use the 3D virtual prototyping software, with instruction given primarily by the tutorial. They were able to control first hand the process of starting from 2D patterns, defining 3D properties and stitch seams, and finally simulating the 3D virtual prototype. After the interactive “hands-on session” they were instructed to complete the rest of the follow-up assessment, containing a repeat of the 12 technology acceptance items.



The six items measuring post hands-on ease of use had a reliability coefficient of .87. A composite post hands-on ease of use variable (COMPEOUH) was computed. The COMPEOUH for the hands-on group fell closest on the scale to “Quite Likely,” ( $M = 5.93$ ,  $SD = .55$ ). Both items rating the highest and lowest were the same as found in the whole sample after viewing the tutorial only; “It would be easy for me to become skillful at using 3D virtual prototype simulations” was the highest ( $M = 6.33$ ,  $SD = .78$ ) and “My interaction with 3D virtual prototyping simulations would be clear and understandable” was the lowest ( $M = 5.67$ ,  $SD = .65$ ). These findings indicate that participants in the hands-on sessions found the 3D virtual prototyping software easier to use than participants who only viewed the tutorial and didn’t use the software.

Findings by course level are not as relevant for the hands-on session group as 99% of the participants were from the 200 level group. As discussed earlier, the difference in participation between course levels may have been due to instructors for the 200 level students offering extra credit for student participation, as well as time constraints within the 300 level or higher student group because of more complex end-of-semester projects. The one participant in the hands-on session from the 300 level or higher group did have higher means for each of the six perceived ease of use items, indicating that 300 level or higher students may find the 3D virtual prototype simulations easier use either due to more patternmaking experience or more exposure to computer-aided design software. However this could be further examined in future studies.

Similar to post hands-on perceived ease of use, the six items measuring post hands-on perceived usefulness had a reliability coefficient of .95. A composite variable was computed (COMPUH) with the perceived usefulness of the software after the hands-on session found to be “Quite Likely,” ( $M = 6.22$ ,  $SD = .69$ ). Out of the six items measuring post hands-on perceived usefulness the item with the highest mean “Quite Likely” ( $M = 6.33$ ,  $SD = .78$ ) was “Using 3D virtual prototype simulations in my work would enable me to accomplish tasks more quickly.” This was supported by a participant’s comments written after the hands-on sessions, “It would save a lot of time and money on mock-ups.” Primarily, the comments after the hands-on sessions were focused on the usefulness for visualization. For example, students observed the possibility of using the software to “experiment with altering virtual pattern pieces and evaluate fit” and that it was helpful to “see both the 2D and 3D forms together and to see the changes immediately.”

### **Analysis of Hypotheses**

The following section will discuss the findings related to the proposed eight null hypotheses.

$H_0$ : Computer self-efficacy will have no impact on student perceptions of the ease of use of the 3D virtual prototyping software.

The hypothesis was not supported. The relationship between computer self-efficacy (CSE) and student perceptions of ease of use (EOU) was tested using an independent samples t-test. For individuals with high CSE, the EOU was found to be “Slightly Likely” ( $M = 5.24$ ,  $SD = .85$ ) which was significantly higher than the EOU ( $M$

= 4.60,  $SD = .98$ ) of individuals with lower CSE,  $t(38) = 2.18$ ,  $p = .036$ . Within the individual EOU items, two showed significant difference related to CSE. One item was “I would find it easy to get 3D virtual prototype simulations to do what I want it to do,” which had a significantly higher EOU ( $M = 5.15$ ,  $SD = .81$ ) for students with high CSE than found in students with low CSE ( $M = 4.35$ ,  $SD = 1.46$ ),  $t(38) = 2.14$ ,  $p = .039$ . The next item with a significantly higher EOU ( $M = 5.30$ ,  $SD = .98$ ) for students with high CSE was “I would find 3D virtual prototype simulations easy to use,” which was rated lower ( $M = 4.15$ ,  $SD = 1.39$ ) by individuals with low CSE,  $t(38) = 3.03$ ,  $p = .004$ . This supports findings from the literature review that demonstrated that higher computer self-efficacy resulted in higher perceived ease of use (Venkatesh & Davis, 1996).

If viewed by course level, there was no significant difference between the EOU of high and low CSE individuals in the 200 level group, even though EOU ( $M = 5.12$ ,  $SD = .75$ ) for those with high CSE was higher than the EOU ( $M = 4.73$ ,  $SD = 1.01$ ) for those with low CSE,  $t(22) = 1.06$ ,  $p = .300$ . This was true for both the composite CSE as well as the individual items. Therefore the difference in the composite mean for the whole sample may have been influenced more by the 300 level or higher group, which had a higher EOU ( $M = 5.38$ ,  $SD = .99$ ) for individuals with high CSE than the EOU ( $M = 4.38$ ,  $SD = .96$ ) for those with low CSE, even though the difference wasn’t significant,  $t(14) = 2.03$ ,  $p = .061$ . However, two individual EOU items within the 300 level or higher group did have means significantly different dependent on level of CSE. The mean EOU for both statements “I would find it easy to get 3D virtual prototype simulations to do what I

want it to do,” ( $M = 5.33$ ,  $SD = 1.00$ ) and “I would find 3D virtual simulations easy to use” ( $M = 5.56$ ,  $SD = .88$ ) were significantly higher for individuals with high CSE,  $t(14) = 2.52$ ,  $p = .024$ ,  $t(14) = 2.53$ ,  $p = .024$ , respectively. As discussed earlier, higher CSE in the 300 level or higher group was likely due to more exposure to a variety of software use in coursework therefore increasing their confidence in computer use and perceived ease of use of software.

$H_0$ : Computer self-efficacy will have no impact on student perceptions of the usefulness of the 3D virtual prototyping software.

This hypothesis was supported. The relationship between computer self-efficacy (CSE) and student perceptions of usefulness (U) was tested using an independent samples t-test. While individuals with high CSE did have a higher perception of usefulness ( $M = 5.68$ ,  $SD = .85$ ) than individuals with low CSE ( $M = 5.33$ ,  $1.22$ ), the difference was not statistically significant,  $t(38) = 1.05$ ,  $p = .301$ . Individuals with low CSE were fairly unsure of the ease of use of 3D virtual prototyping, rating 67% of the ease of use items as “neither” likely or unlikely, however those individuals did find 100% of the usefulness items to be at least “slightly likely.” The usefulness item “I would find 3D virtual prototype simulations useful in my job” was found to be “quite likely” by both high and low CSE individuals.

If viewed by course level, there was no significant difference between the mean of perceived usefulness in high and low CSE individuals from the 200 level group, even though usefulness for those with high CSE ( $M = 5.55$ ,  $SD = .72$ ) was higher than those with low CSE ( $M = 5.37$ ,  $SD = 1.26$ ),  $t(22) = .404$ ,  $p = .690$ . Within the 200 level group there were no significant differences in means of individual items

of perceived usefulness between the high and low CSE groups. Individuals at the 200 level with higher CSE gave the item “I would find 3D virtual prototype simulations useful in my work” a higher mean perceived usefulness ( $M = 6.00$ ,  $SD = .89$ ) than individuals with lower CSE ( $M = 5.38$ ,  $SD = 1.61$ ). This differed from the item, “Using 3D virtual prototype simulations in my work would enable me to accomplish task more quickly” which was given the highest mean perceived usefulness ( $M = 5.89$ ,  $SD = 1.62$ ) by individuals with high CSE at the 300 or higher level. This indicates that individuals with high CSE from the 300 level or higher group found more usefulness in the 3D virtual prototype simulations in terms of speeding up the apparel design process. These individuals had more coursework involving the construction of sample garments than individuals in the 200 level and perhaps were more impressed by potential time savings inherent in virtual prototyping. However 300 level or higher students with low CSE, who had a mean perceived usefulness for that item ( $M = 4.71$ ,  $SD = 1.50$ ) may have felt that using the software was potentially as time consuming as it would be to create a physical prototype.

$H_0$ : General spatial ability will have no impact on student perceptions of the ease of use of the 3D virtual prototyping software.

This hypothesis was supported. The relationship between general spatial ability and student perceptions of ease of use (EOU) was tested using an independent samples t-test. The mean EOU by individuals with high general spatial ability ( $M = 5.11$ ,  $SD = .97$ ), while higher, did not differ significantly from the mean perception of EOU of individuals with low general spatial ability ( $M = 4.73$ ,  $SD = .94$ ),  $t(38) = 1.27$ ,  $p = .212$ .

Across the individual items of perceived ease of use, the means were higher for individuals with high general spatial ability than those found in individuals with low general spatial ability, but not significantly higher. The item with the most difference in perceived ease of use between high and low general spatial ability was, “I would find it easy to get 3D virtual prototype simulations to do what I want it to do.” Individuals with high general spatial ability thought it would be “quite likely” that they could get the 3D virtual prototype simulation to do what they want it to do ( $M = 5.05$ ,  $SD = 1.15$ ), compared to those with low general spatial ability who felt it was neither likely nor unlikely ( $M = 4.45$ ,  $SD = 1.28$ ).

When viewed by course level there was also no significant difference in the mean perceived ease of use between high and low general spatial ability. The only item with a mean showing significant difference was found in the 200 level group. Again it was the item “I would find it easy to get 3D virtual prototype simulations to do what I want it to do.” The 200 level individuals with high general spatial ability had a mean perceived ease of use ( $M = 5.40$ ,  $SD = .516$ ) that was significantly higher than those with low general spatial ability ( $M = 4.36$ ,  $SD = 1.34$ ),  $t(22) = 2.33$ ,  $p = .029$ . As low general spatial ability ( $M = 14.36$ ,  $SD = 6.69$ ) within the 200 level group is the lowest of the whole sample, it seems apparent that while the findings are not significant, individuals with lower general spatial ability are fairly unsure, stating that it would be neither likely nor unlikely that 3D virtual prototyping would be easy to use.

$H_0$ : General spatial ability will have no impact on student perceptions of the usefulness of the 3D virtual prototyping software.

This hypothesis was supported. The relationship between general spatial ability and student perceptions of usefulness (U) was tested using an independent samples t-test. The mean perception of usefulness by individuals with high general spatial ability ( $M = 5.50$ ,  $SD = 1.25$ ) did not differ significantly from the mean perception of usefulness by individuals with low general spatial ability ( $M = 5.51$ ,  $SD = .85$ ),  $t(38) = 1.27$ ,  $p = .212$ . It is, however, interesting that mean perceived usefulness in individuals with low general spatial ability was slightly higher than for individuals with high spatial ability.

Within the items measuring usefulness, several had higher means from the low general spatial ability group, such as; “Using 3D virtual prototype simulations in my work would enable me to accomplish my tasks more quickly,” ( $M = 5.55$ ,  $SD = 1.73$ ) and “Using 3D virtual prototype simulations would improve my work performance,” ( $M = 5.50$ ,  $SD = 1.19$ ). This would indicate that while both groups found the 3D virtual prototype simulations slightly easy to use, the low general spatial ability group saw slightly more usefulness in the 3D virtual prototype simulations in terms of speeding up the process and improving their work performance. They may have found the 3D virtual prototypes easier to create than their own mental visualizations. When viewed by course level no significant differences in the perceived usefulness were found between individuals with high and low general spatial ability.

$H_0$ : Apparel specific spatial ability will have no impact on student perceptions of the ease of use of the 3D virtual prototyping software.

This hypothesis was not supported. As the scores were divided into high, average and low, relationship between apparel spatial visualization (ASVT) ability and student perceptions of ease of use (EOU) was tested using a Oneway ANOVA analysis. Among the three groups of ASVT scores, the difference between the perceived ease of use means (High [ $M = 5.35$ ,  $SD = 1.00$ ], Average [ $M = 4.51$ ,  $SD = .62$ ], Low [ $M = 4.67$ ,  $SD = .96$ ]) was slightly significant,  $F(2,37) = 3.36$ ,  $p = .045$ .

Within the items measuring perceived ease of use, some were found to have significant or slightly significant differences in means between the levels of apparel spatial ability (see Table 2). The item measuring mean perceived ease of use with the most significant difference among the groups was "Learning to operate 3D virtual prototype simulations would be easy for me." Individuals with high ASVT scores

**Table 2. Technology Acceptance by ASVT (Ease of Use)**

		<b>N</b>	<b>M</b>	<b>p</b>
<b>Perceived Ease of Use</b>	high	17	5.35	0.045
	med	10	4.52	
	low	13	4.68	
Learning to operate 3D virtual prototype simulations would be easy for me.	high	17	5.71	0.010
	med	10	4.40	
	low	13	5.00	
I would find it easy to get 3D virtual prototype simulations to do what I want it to do.	high	17	5.18	0.147
	med	10	4.60	
	low	13	4.31	
My interaction with 3D virtual prototype simulations would be clear and understandable.	high	17	4.94	0.207
	med	10	4.00	
	low	13	4.69	
I would find 3D virtual prototype simulations to be flexible to interact with.	high	17	5.41	0.148
	med	10	4.50	
	low	13	4.85	
It would be easy for me to become skillful at using 3D virtual prototype simulations.	high	17	5.76	0.055
	med	10	4.90	
	low	13	5.00	
I would find 3D virtual prototype simulations easy to use.	high	17	5.12	0.192
	med	10	4.70	
	low	13	4.23	



thought that it would be quite likely that learning to operate 3D virtual prototype simulations would be easy, compared to individuals with medium ASVT scores who felt the ease of learning to use the software would be neither likely nor unlikely. This item was also found to have significant difference in mean ASVT scores within the 300 level or higher group, but not in the 200 level.

$H_0$ : Apparel specific spatial ability will have no impact on student perceptions of the usefulness of the 3D virtual prototyping software.

This hypothesis was supported. As the scores were divided into high, average and low, the relationship between apparel spatial visualization (ASVT) ability and student perceptions of usefulness (U) was tested using a Oneway ANOVA analysis. Among the three groups of ASVT scores, the difference between the perceived usefulness means (High [ $M = 5.83$ ,  $SD = .99$ ], Average [ $M = 4.86$ ,  $SD = .98$ ], Low [ $M = 5.57$ ,  $SD = 1.05$ ]) was not statistically significant,  $F(2,37) = 2.95$ ,  $p = .065$ . Within the items measuring perceived usefulness, only one significant difference was found among the levels of apparel spatial ability (see Table 3). This was found on the item, "Using 3D virtual prototype simulations would make it easier to do my work." This item was also found to have significant difference in mean ASVT scores within the 300 level or higher group, but not in the 200 level. Again it was the individuals with high apparel spatial ability who felt it was quite likely the software would be useful for their work.

**Table 3. Technology Acceptance by ASVT (Usefulness)**

		<b>N</b>	<b>M</b>	<b>p</b>
<b>Perceived Usefulness</b>	high	17	5.83	0.065
	med	10	4.87	
	low	13	5.58	
Using 3D virtual prototype simulations in my work would enable me to accomplish tasks more quickly.	high	17	5.82	0.095
	med	10	4.60	
	low	13	5.31	
Using 3D virtual prototype simulations would improve my work performance.	high	17	5.71	0.239
	med	10	4.90	
	low	13	5.62	
Using 3D virtual prototype simulations in my work would increase my productivity.	high	17	5.71	0.092
	med	10	4.70	
	low	13	5.54	
Using 3D virtual prototype simulations would enhance my effectiveness in my work.	high	17	5.88	0.133
	med	10	5.10	
	low	13	5.85	
Using 3D virtual prototype simulations would make it easier to do my work.	high	17	5.65	0.021
	med	10	4.40	
	low	13	5.62	
I would find 3D virtual prototype simulations useful in my work.	high	17	6.24	0.222
	med	10	5.50	
	low	13	5.54	

Overall findings show that the highest ASVT scores were found in the 300 level or higher group, and the items with most significant differences in mean EOU and U were also found within the 300 level or higher as opposed to the 200 level. This indicates support for the conclusions of previous studies that individuals with higher spatial ability would have more positive attitudes toward using 3D simulations (Huk, Steinke, & Floto, 2003). However the fact that individuals with low spatial ability had slightly positive attitudes about use of 3D simulations suggests that their use in the classroom could still be beneficial for the majority of students.

A potential reason the findings for the ASVT hypotheses were different in comparison to those for general spatial ability could be the fact that ASVT measures domain specific spatial ability and the 3D virtual prototyping software used in this research was also industry specific. Therefore the spatial ability measured by the

ASVT is more relevant to understanding the influence of specific visualization skills on the user acceptance of 3D virtual prototype simulations used in apparel design.

$H_0$ : Student perceptions of the ease of use of the 3D virtual prototyping software will not differ under two conditions; exposure by tutorial only vs. exposure by additional hands-on session.

This hypothesis was not supported. In order to test the relationship between perceptions after the tutorial and perceptions after the hands-on session, a paired samples t-test was used. After the hands-on session, the perceived ease of use ( $M = 5.93$ ,  $SD = .55$ ) was significantly higher than the perceived ease of use collected after exposure by tutorial only ( $M = 4.88$ ,  $SD = 1.16$ ),  $t(11) = -3.03$ ,  $p = .011$ .

Within the items measuring perceived EOU, the majority was found to have significant differences in means under the two different conditions (see Table 4). One of the items showing the most significantly different mean for perceived ease of use after the hands-on session was, "I would find 3D virtual prototype simulations easy to use." This item was found to be slightly likely before the hands-on session ( $M = 4.75$ ,  $SD = 1.29$ ) but after the hands-on session it increased to a strong "Quite Likely" ( $M = 6.08$ ,  $SD = .67$ ).

It is possible that before the hands-on session it was difficult to determine just how easy it would be to use the software. One of the user comments, related to usability, made before the hands-on session supported this, "The toolbars of the software shown in the tutorial seem rather ambiguous (hard to navigate menus) and have tiny icons." This type of menu and icon confusion may have been cleared up once software was seen full-size during the hands-on session.

**Table 4. Technology Acceptance Before/After Hands-on Session**

		<i>M</i>	<i>p</i>
<b>Perceived Ease of Use</b>	Before	4.89	0.011
	After	5.93	
Learning to operate 3D virtual prototype simulations would be easy for me.	Before	5.17	0.206
	After	5.75	
I would find it easy to get 3D virtual prototype simulations to do what I want it to do.	Before	4.58	0.023
	After	5.75	
My interaction with 3D virtual prototype simulations would be clear and understandable.	Before	4.67	0.067
	After	5.67	
I would find 3D virtual prototype simulations to be flexible to interact with.	Before	4.92	0.02
	After	6.00	
It would be easy for me to become skillful at using 3D virtual prototype simulations.	Before	5.25	0.008
	After	6.33	
I would find 3D virtual prototype simulations easy to use.	Before	4.75	0.006
	After	6.08	
<b>Perceived Usefulness</b>	Before	5.67	0.01
	After	6.22	
Using 3D virtual prototype simulations in my work would enable me to accomplish tasks more quickly.	Before	5.50	0.017
	After	6.33	
Using 3D virtual prototype simulations would improve my work performance.	Before	5.75	0.096
	After	6.17	
Using 3D virtual prototype simulations in my work would increase my productivity.	Before	5.67	0.026
	After	6.17	
Using 3D virtual prototype simulations would enhance the effectiveness of my work.	Before	5.92	0.104
	After	6.25	
Using 3D virtual prototype simulations would make it easier to do my work.	Before	5.25	0.002
	After	6.17	
I would find 3D virtual prototype simulations useful in my work.	Before	5.92	0.22
	After	6.25	

$H_0$ : Student perceptions of the usefulness of the 3D virtual prototyping software will not differ under two conditions; exposure by tutorial only vs. exposure by additional hands-on session.

This hypothesis was not supported. In order to test the relationship between perceptions after the tutorial and perceptions after the hands-on session, a paired samples t-test was used. After the hands-on session, the perceived usefulness ( $M = 6.22$ ,  $SD = .687$ ) was significantly higher than the perceived usefulness found after exposure by the tutorial only ( $M = 5.67$ ,  $SD = .80$ ),  $t(11) = -3.12$ ,  $p = .010$ .

Within the items measuring perceived usefulness, the majority was found to have significant differences in means under the two different conditions (see Table 4). One of the items showing the most significantly different means for perceived usefulness after the hands-on session was, "Using 3D virtual prototype simulations would make it easier to do my work" ( $M = 6.17$ ,  $SD = .84$ ). However this item was found to be quite likely under both conditions. User comments related to perceived usefulness before and after the hands-on session were overall positive. For example, one participant before the hands-on session commented: "It seems like something that would be extremely useful in the industry especially if the person using it knew how to use it really well." After the hands-on session one participant commented, "I feel it is a very useful. It would definitely help in the waste of fabrics for 1st and 2nd garment trials."

## **Discussion**

Reaction to the simulation of the 3D virtual prototype was overall very positive. Participants were overheard to exclaim, "cool" and "this is amazing." Out of the 40 completed main assessments, 30 participants took the time to write comments for the item requesting their overall perception of 3D virtual prototyping software and its potential use in instruction of apparel design. Several of those comments were used in earlier discussion in support of findings.

Observations made by the researcher during the hands-on sessions were mainly in reference to use of the tutorial. One example of confusion by users was that the instructions did not always say to click "OK" or "Apply" after making some

change in a dialogue box. While some of the students were able to make the decision to take those actions on their own, others were confused when nothing happened. Tutorials that guide students through a step-by-step process often need to be quite thorough as there is a tendency by students to blindly follow the steps rather than pausing to think for themselves. Software interfaces that closely resemble the common look and feel of programs that run on Microsoft Windows operating system can be beneficial, as basic functions are then intuitive. For example, one participant found “Edit, Undo” in the menu without its location or use described in the tutorial.

As seen in the findings for computer self-efficacy, the majority of sample participants were moderately confident in their ability to use a computer to complete some specific task. Only a few of the hands-on session participants needed guidance outside of what was provided in the tutorial. Usability problems were commonly the result of incorrect selections made on the 2D patterns when a point was clicked rather than a line, or vice versa. Control of zoom level and rotation were also difficult for some participants. These are typical difficulties for many just beginning to learn any vector based design program, such as Adobe Illustrator. Therefore at least some of the basic 2D manipulation skills from Adobe Illustrator could be transferable to 2D CAD for patternmaking.

As one of the purposes of the study was to identify the potential for effectively implementing use of 3D virtual prototyping in the classroom, it is useful to review the student suggestions. For example, 92% of the hands-on session participants said that virtual prototyping software would be useful for instruction of apparel

patternmaking / design concepts. As discussed earlier, 100% of the hands-on session participants felt that tutorials such as the one used in this research would be useful for learning 3D virtual prototyping software. Other suggestions related to using the software in the classroom, such as “I feel lab demonstrations help me understand software the best. That paired with required projects and assignments would help me learn.” Demonstrations, handouts and lab activities were mentioned several times. Also suggested was using the software for a project that would incorporate both apparel and textile design, “I think it would be really beneficial to create your own fabric in classes like 321 [Computer Integrated Textile and Fashion Design] and then be able to see it on a pattern that you have drafted in classes like 225 [Patternmaking I] and 325 [Patternmaking II].”

Other comments included suggestion about which course level should use the software, such as “Introducing the program to 200 level students would make it easy to transition later and make this most effective.” However another student did comment that it would be more useful for advanced students, “I think that this software would be really helpful for higer [sic] level design classes.” One multiple choice item in the hands-on session assessment asked participants to select multiple course levels at which they felt working with 3D virtual prototyping software would be appropriate. Selections were made for both 200 and 300 level by 58% of the participants, with 400 level next at 33% and 100 level last at 25%.

One of the most interesting findings from the pilot study was that a somewhat low percentage, 50% of students from Patternmaking II, responded that they had used CAD for patternmaking, even though a unit on CAD is introduced in the

prerequisite Patternmaking I course. This indicated that the exposure to CAD was easily forgotten and had little impact. With the majority of the present study's sample giving positive comments about the potential to use 3D virtual prototyping software, it would seem that exposure to 2D to 3D CAD concepts could improve student retention of CAD experiences. One participant commented, "This is so awesome! I would love to work with the software more. To learn more, and to do more extensive work with this. I feel I learned many useful things from just this little bit that I know. I am interested to see how this technology works out!"



## **CHAPTER 5: CONCLUSIONS**

### **Summary**

The process of apparel design requires much 2D/3D visualization. In apparel design education, flat pattern drafting courses introduce students to skills necessary to design 2D patterns required for construction of a 3D garment. Techniques demonstrated in draping courses introduce students to skills necessary to first design the 3D garment and then to create the 2D patterns. Both methods of manual patternmaking can be enhanced and made more accurate with computer-aided design tools. Therefore 2D and 3D visualization can be continued in a digital environment. An advanced technology in the beginning stages of adoption by the apparel industry is computer-aided design software capable of simulating 3D virtual prototypes, providing an opportunity to increase visualization skills for apparel design students.

The purpose of this study was to examine the influence of computer self-efficacy and spatial visualization ability on student perceptions of 2D/3D CAD virtual prototype simulations for apparel design. A research design with a focus on measuring the computer self-efficacy, general spatial ability and apparel spatial visualization ability of college-aged apparel design students was implemented. An online tutorial was developed to introduce the whole sample to 3D virtual prototype simulations. Delivery of the survey and tutorial was via a WebCT assessment. A focus group made use of the tutorial while using the 3D virtual prototype software during hands-on sessions. The technology acceptance constructs of perceived

ease of use and perceived usefulness were measured before and after the hands-on sessions.

The sample was found to have above average confidence in their ability to perform specific tasks using a computer. The relatively high computer self-efficacy level of the sample was supported by literature describing this generation of students as “digital natives” and “tech savvy” (Oblinger & Oblinger, 2005). This study found that computer self-efficacy did influence the perceived ease of use of 3D virtual prototype software. Individuals with high computer self-efficacy found the software easier to use than individuals with low computer self-efficacy.

General spatial ability and apparel spatial ability were found to be comparable to similar samples from other studies. Both were found to be higher in the individuals that had completed more advanced coursework. General spatial ability was not found to influence technology acceptance. Apparel spatial visualization ability was found to influence the perceived ease of use of 3D virtual prototyping software. Individuals with high apparel spatial visualization ability found 3D virtual prototype software easier to use than those with lower apparel spatial visualization ability.

Overall, after introduction to 3D virtual prototype simulations via a tutorial, the whole sample perceived the software to be somewhat easy to use and to be useful. Comments made by participants about 3D virtual prototype simulations were overall very positive. After a focus group had direct interaction with the software, the perceived ease of use and usefulness increased significantly. Therefore it is

apparent that a tutorial combined with instructor assistance would be necessary for more effective and meaningful use of the software.

Another purpose of this study was to provide insight for educators on the use of 3D virtual prototyping simulations as a learning tool. In order to introduce the technology to students for maximum learning and understanding it would be beneficial to implement units at both the beginning and advanced levels. Participants suggested that the simulations would be useful for beginning patternmakers who may have difficulty visualizing 2D flat patterns as a 3D garment. At the advanced level one suggestion was to use 3D virtual prototypes constructed from patterns developed in flat pattern and draping courses, with textile designs applied from a computer-aided textile design course.

Today's students are members of the "Net Generation" who are both visually and digitally literate, and intrigued by new technologies (Oblinger & Oblinger, 2005). They are experiential learners who have high visual-spatial skills and an ability to switch between virtual and physical worlds quickly (Oblinger & Oblinger, 2005). Several of them indicated that if they had assistance, such as in the form of "online help" or a tutorial, they would be extremely confident in their ability to learn and use even advanced software.

The Net Generation has a preference for image-rich environments, sometimes demanding instructions using graphic layout (Oblinger & Oblinger, 2005). Therefore online tutorials would be successful in the classroom setting, meeting both the students' digital and visual needs. The image-rich tutorial used in this study was found to be useful by 100% of the hands-on participants. Though tutorials are

helpful, lab activities that involve hands-on use of technology, such as troubleshooting design flaws using 3D virtual prototype simulations, would appeal to the experiential nature of these students.

The pessimists I encountered at a software user's convention were wrong - 3D virtual prototype software is not a "gimmick" and students of apparel design, future apparel industry professionals, have deemed it "useful." While the software can still be considered advanced technology, it is not too difficult for "beginner" or student users to work with. On the contrary, one of the main advantages of 3D virtual prototype software is its usefulness as a visualization tool by beginner level students with low spatial ability. However even individuals with high spatial ability declared the software to be easy to use and saw its usefulness for reducing time and waste involved with first physical prototypes. More importantly, just this brief interaction with the software was found to be engaging, eliciting comments that expressed eagerness to use it in class projects. With full implementation in coursework, 3D virtual prototyping software would generate even more student excitement, further increase student visualization opportunities and provide a valuable skill set for future careers.

### **Limitations and Recommendations**

There were several limitations to this study that need to be considered, as well as recommendations for future research. One of the limitations was related to the delivery of the online instrument. To reduce the possibility of answer sharing and discussions between participants, the completion of the online instrument's main

survey assessment should be better controlled, such as scheduling groups to complete the survey under monitored lab conditions. Timed or observed completion of the test of general spatial visualization and ASVT would provide more insights for student visualization processes. To take advantage of the online format, future studies should make the assessment accessible to a larger population, such as textiles and clothing students enrolled at universities worldwide.

Use of the full Surface Development Test, consisting of two parts, or other tests of general spatial ability, would result in a more reliable and validated “general” score. The ASVT may benefit from modifications to the 2D pattern sets so that the pieces had more clarity in their style and design features. Digitizing the 2D pattern sets used in the ASVT would allow for use of actual 3D virtual prototype images rather than stylized 2D sketches. Development of a 3D to 2D test would then be possible, with the student allowed to view and rotate a 3D virtual prototype and then tested on their selection of the appropriate 2D patterns from a mixed set.

Utilization of computer-aided instruction modules, making use of 3D virtual prototypes, would add enhance instruction of Patternmaking I. One example would be to combine recorded flat pattern instruction demonstration clips with images from a similar 2D/3D computer-aided design workflow. After each flat pattern manipulation was shown manually and as steps in CAD, the process would be taken one step further with a video or Flash animation of the 2D patterns draped onto a virtual model using 3D virtual prototype simulation. CAI modules made available for download by the students for self-paced use during or outside of class time would provide additional visual learning resources.

Early introduction of 3D virtual prototypes would give beginning level student more exposure to 2D and 3D visuals and introduce them to software they would use more interactively in advanced patternmaking classes. Tutorials and lab activities for virtual prototyping of more detailed or structured garments should be introduced at different course levels. Pre and post-tests of spatial visualization done before and after a semester of 3D virtual prototyping software used in coursework would allow for examination of improvements in spatial ability skills.

Students in Patternmaking II and other advanced design courses would benefit from the opportunity to digitize their patterns. This would give students more opportunities to work interactively with the 3D software, designating the appropriate sewn seams for simulation of a virtual sample. Using a virtual prototype for troubleshooting the order of assembly and fit evaluations, with adjustments made to the digital 2D patterns before the first physical sample was made, would result in reductions in material, time and stress. Classroom design critiques could be done twice, first using the virtual sample and finally live, with the final garment.

The assessment of the ease of use and usefulness of a design or fit session held in the virtually realistic environment may be possible. Future research should examine the fit evaluation of 3D virtual prototypes in a virtually realistic environment compared to “live” sessions. Studies should be done on the influence of spatial visualization ability on student perceptions of virtual prototypes seen in actual 3D, such as in an immersive virtually realistic environment. Tools for interactive design changes, made directly on the 3D virtual prototype as opposed to the 2D pattern pieces, should be further developed and tested.

## APPENDIX A: PERMISSION TO USE ASVT

**From:** Jo Kallal <JKALLAL@UDel.Edu>  
**Subject:** **Re: ASVT**  
**Date:** September 4, 2007 12:03:52 PM CDT  
**To:** Sandra Stewart <sandras@iastate.edu>  
**Cc:** Jane Workman <jworkman@siu.edu>

---

Hi Sandra: I have been out of town and apologize for the delay in responding.

Yes, this is fine with me as well. I would also like a copy of the online instrument and a copy of your results at some point. Good luck!. Please forward my regards to Jean as well.

jo

M. Jo Kallal, Professor  
Fashion & Apparel Studies  
204 ALW p: 302.831.1271  
University of Delaware f: 302.831.6081  
Newark, DE 19716 e: [jkallal@udel.edu](mailto:jkallal@udel.edu)

On Aug 22, 2007, at 13:50, Jane Workman wrote:

Hello, Sandra,

It is all right with me if it is all right with Dr. Kallal. I would like to request that you send me a copy of the online instrument. I might be able to use it in my research program!

Sincerely,

Jane Workman

## APPENDIX B: PERMISSION TO USE VZ-3



Office of the General Counsel

September 25, 2007

Sandra Stewart  
Iowa State University  
AESHM  
31 MacKay Hall  
Ames, IA 50014

Dear Ms. Stewart:

Thank you for your request to use ETS's copyrighted Kit of Factor-Referenced Cognitive Test materials listed in the attached Appendix. We understand you will be incorporating these materials as part of your online survey instrument. It is also understood that this site is password protected.

Educational Testing Service is pleased to grant permission to you to reprint the Kit of Factor-Referenced Cognitive Test materials as specified in the attached Appendix on your secure website. The following terms apply to this permission:

1. The materials are to be used only for the purposes described in your email and are not to be distributed, published, or posted, transmitted or used in any other manner without written permission from ETS.
2. This permission is nonexclusive, nontransferable and subject to a fee of \$55.00. Please send a check payable to Educational Testing Service to my attention at Educational Testing Service, Office of General Counsel, Mail Stop 04-C, Rosedale Road, Princeton, NJ 08541.
3. The following credit line and disclaimer statement will be printed on each screen or file where the materials appear:  
  
"Reprinted by permission of Educational Testing Service, the copyright owner. No Endorsement of this website by ETS should be inferred."
4. The ETS copyrighted KIT materials will not be modified in any manner.
5. This permission applies to use of the KIT materials in the above-referenced website only, and includes a two year-term, commencing September 25, 2007, and ending September 24, 2009. Permission may be renewed at that time.

Educational  
Testing Service  
Rosedale Road MS23C  
Princeton, NJ 08541  
phone: (609) 734-5071  
fax: (609) 734-1700  
web: www.ets.org



-2-

6. License fees are due and payable upon signature and must accompany the return of this executed license.
7. This Agreement shall be considered null and void if not signed and returned within 30 days of the date of this letter and accompanied by payment of the full license fee.
8. It is agreed that any changes in the terms and conditions of this Agreement must be in writing and approved by an authorized representative of ETS.
9. This copyright license may be revoked at any time during the life of the license if you fail to abide by the terms of the Agreement.

If the above arrangements are satisfactory, please sign both copies of this Agreement, and return one to me at the above listed address.

Sincerely,

*Lorraine Carmosino*

Lorraine Carmosino  
Permissions Administrator

cc: R. Ekstrom.

ACCEPTED AND AGREED TO:

BY: 

TITLE: \_\_\_\_\_

DATE: 10/23/07

**From:** "Carmosino, Lorraine" <[lcarmosino@ETS.ORG](mailto:lcarmosino@ETS.ORG)>  
**Date:** March 24, 2008 1:37:36 PM CDT  
**To:** "Sandra Stewart" <[sandras@iastate.edu](mailto:sandras@iastate.edu)>  
**Subject:** RE: Request to use ETS copyrighted KIT test materials

Dear Sandra,

Yes, this is fine. In fact, we are in the process of reviewing dissertation use and Microfilms. You are permitted to use the figure within your text.

Best regards,  
 Lorraine

Lorraine Carmosino  
 Permissions Administrator  
 Office of General Counsel  
 Rosedale Road, MS 04-C  
 Princeton, NJ 08541  
 Voice: +1-609-734-1520  
 Fax: +1-609-734-1690  
 Email: [lcarmosino@ets.org](mailto:lcarmosino@ets.org)

-----Original Message-----

From: Sandra Stewart [<mailto:sandras@iastate.edu>]  
 Sent: Monday, March 24, 2008 1:22 PM  
 To: Carmosino, Lorraine  
 Subject: Re: Request to use ETS copyrighted KIT test materials

Hello,

Thank you again for sending the second licensing agreement, allowing use of the test material in the Appendix.

In the copies I shared with my committee members I did include the materials in the Appendix as per that agreement. I passed my thesis defense and now I'm making final revisions to my thesis to submit to the Graduate College. In this case I think that the stipulation #3 may mean that I'll have to remove the materials from the Appendix. I asked the Graduate College about "University Microfilms, Inc." and they said that the fact the thesis will be made available for purchase through ProQuest probably falls under the same condition.

I understand if the materials should not be made available in the Appendix if published & available through ProQuest. In that case, would it be possible to just use the test's sample figure as an image within the text? Surface Development Test VZ-3

Thank you,  
 Sandra Stewart

**APPENDIX C: HUMAN SUBJECTS APPROVAL****IOWA STATE UNIVERSITY**  
OF SCIENCE AND TECHNOLOGY

Institutional Review Board  
Office of Research Assurances  
Vice President for Research  
1138 Pearson Hall  
Ames, Iowa 50011-2207  
515 294-4566  
FAX 515 294-4267

**DATE:** November 16, 2007

**TO:** Sandra Stewart  
31 MacKay Hall

**CC:** Dr. Jean Parsons  
31 MacKay Hall

**FROM:** Jan Canny, IRB Administrator  
Office of Research Assurances

**IRB ID:** 07-568

**Study Review Date:** 15 November 2007

The Institutional Review Board (IRB) Chair has reviewed the project, "Effects of computer self-efficacy and spatial visualization ability on student perceptions of 3D virtual prototype simulations for instruction of apparel design" (IRB ID 07-568) and has declared the study exempt from the requirements of the human subject protections regulations as described in 45 CFR 46.101(b), Exempt Category (2). A description of this exemption category can be found in the list on the next page. Please note that you must submit all research involving human participants for review by the IRB. Only the IRB may make the determination of exemption, even if you conduct a study in the future that is exactly like this study.

The IRB determination of exemption means that this project does not need to meet the requirements from the Department of Health and Human Service (DHHS) regulations for the protection of human subjects, unless required by the IRB. We do, however, urge you to protect the rights of your participants in the same ways that you would if the project was required to follow the regulations. This includes providing relevant information about the research to the participants.

Because your project is exempt, you do not need to submit an application for continuing review. However, you must carry out the research as proposed in the IRB application, including obtaining and documenting (signed) informed consent if you have stated in your application that you will do so or if required by the IRB.

Any modification of this research should be submitted to the IRB on a Continuation and/or Modification form, prior to making any changes, to determine if the project still meets the Federal criteria for exemption. If it is determined that exemption is no longer warranted, then an IRB proposal will need to be submitted and approved before proceeding with data collection.

## APPENDIX D: PERMISSION TO USE OPTITEX IMAGES

**From:** "Yoram Burg" <yoram.burg@optitex.com>  
**Subject:** **RE: Request to use Screenshots in Research [IA State]**  
**Date:** September 20, 2007 12:48:38 PM CDT  
**To:** "Sandra Stewart" <sandras@iastate.edu>

---

Hi Sandra,

Sorry for my very late reply, we have been quite busy with some interesting projects (see below).

- 1) <http://video.bravotv.com/player/?id=139064#videoid=150198>
- 2) <http://video.accesshollywood.com/player/?id=146584>
- 3) [www.berninamylabel.com](http://www.berninamylabel.com)

You can use screen captures and video's from our website as long as they are properly credited to OptiTex. Please visit the following page for more information and hi res promotional images:  
[http://www.optitex.com/en/About\\_Us/OptiTex\\_Press\\_Kit](http://www.optitex.com/en/About_Us/OptiTex_Press_Kit)

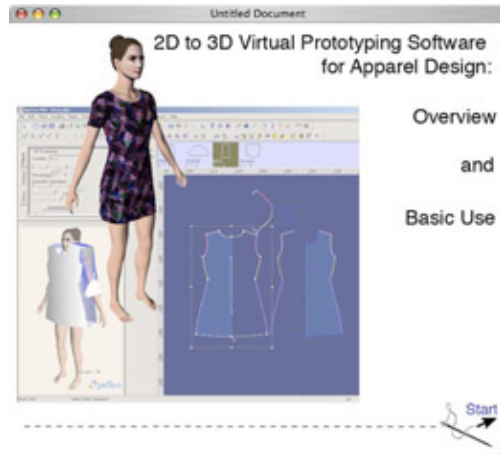
Once again I apologize for the late response and I do look forward for your comments.

Best Regards,

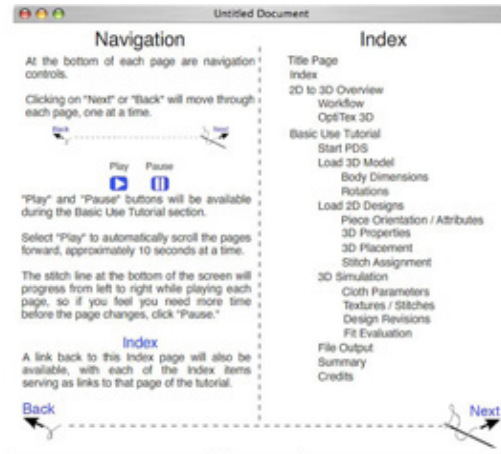
Yoram Burg | OptiTex USA Inc. | [www.optitex.com](http://www.optitex.com)  
Tel: 212-629-9053 x 201 | Efax: +1-260-960-4179



## APPENDIX E: TUTORIAL (STORYBOARD)



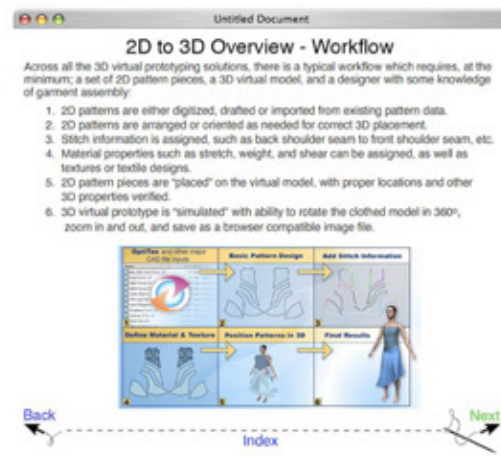
Frame 1



Frame 2



Frame 3



Frame 4



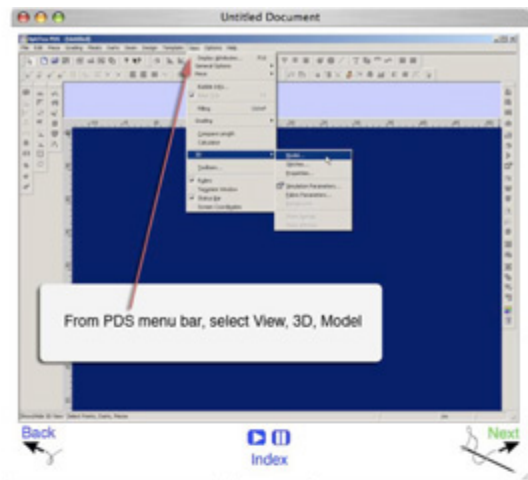
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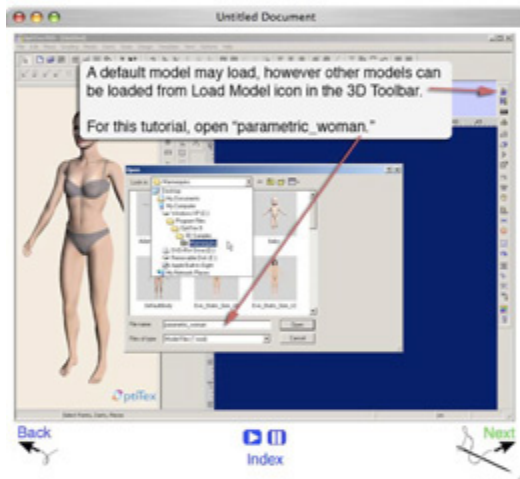
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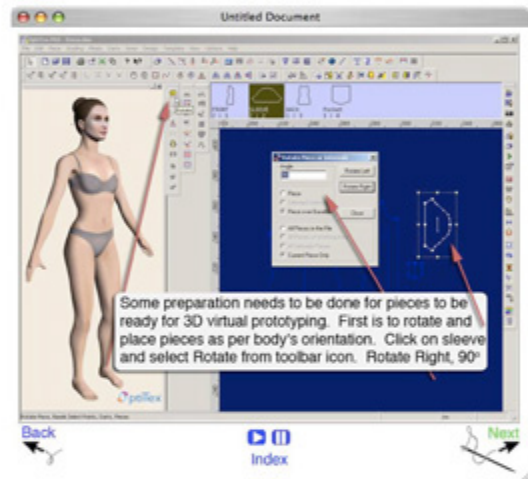
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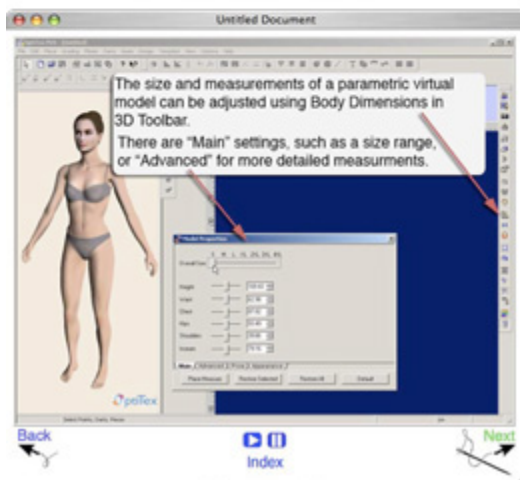
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Frame 9



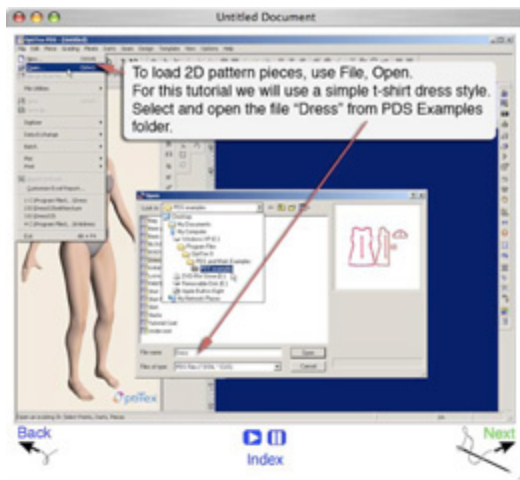
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Frame 11



Frame 12



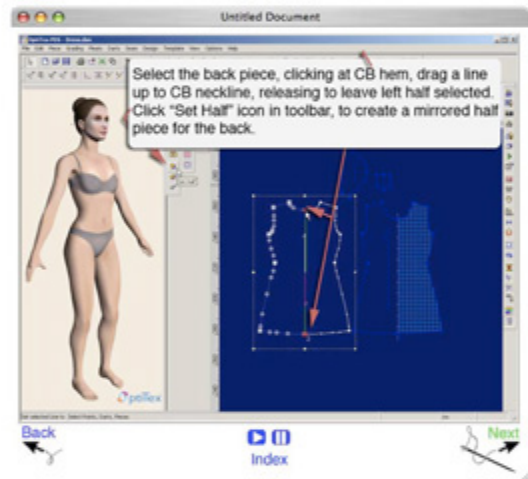
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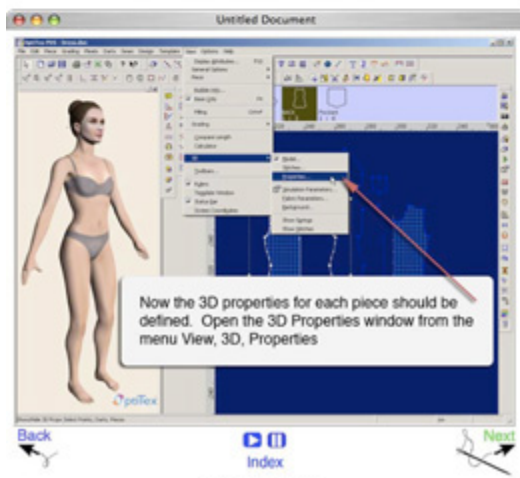
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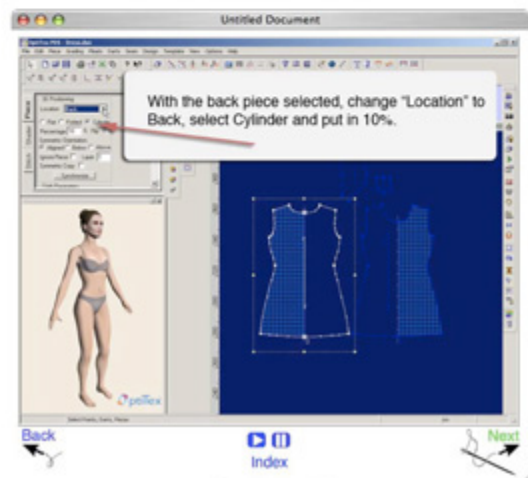
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Frame 16

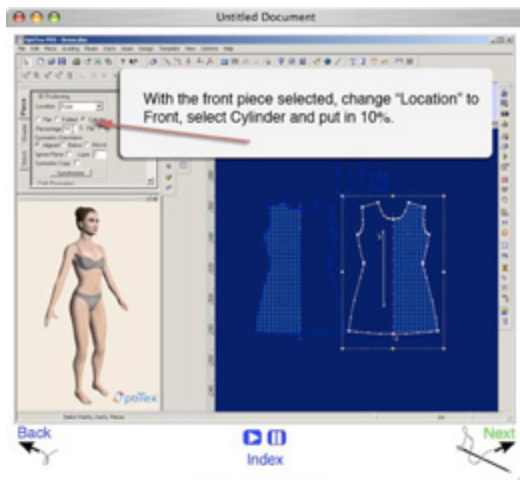


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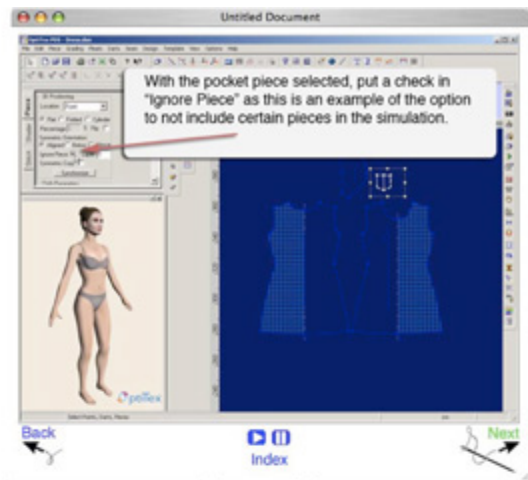


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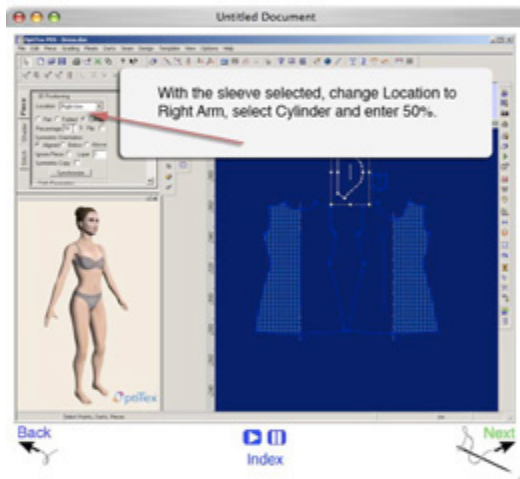




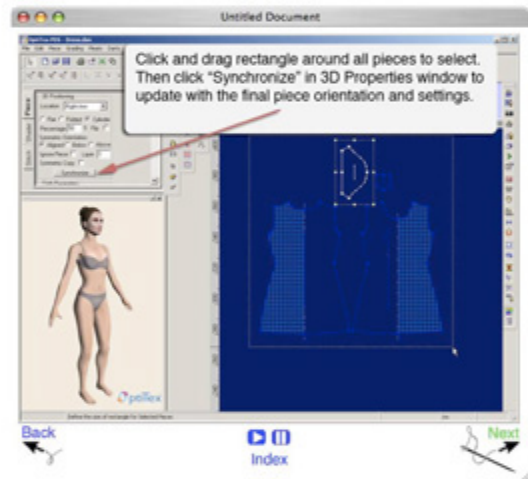
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Frame 20



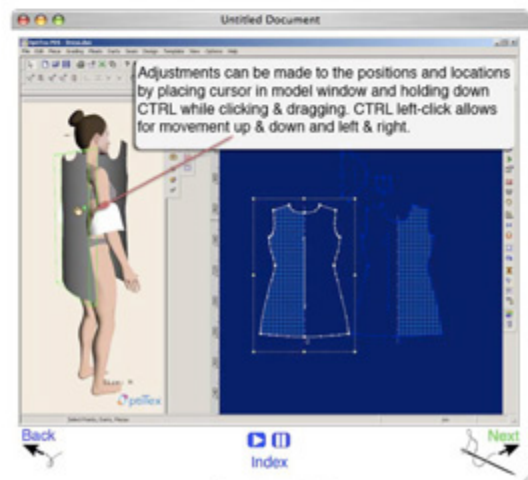
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Frame 22

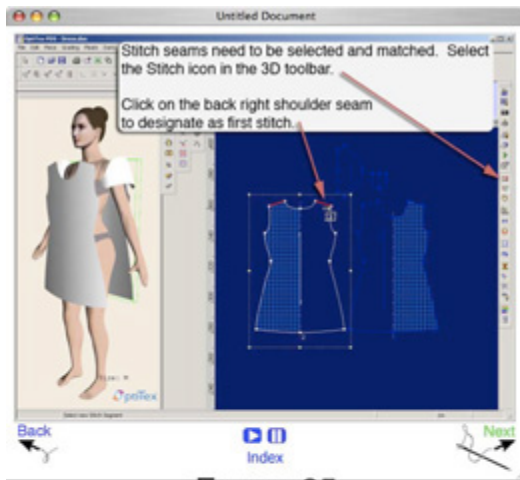


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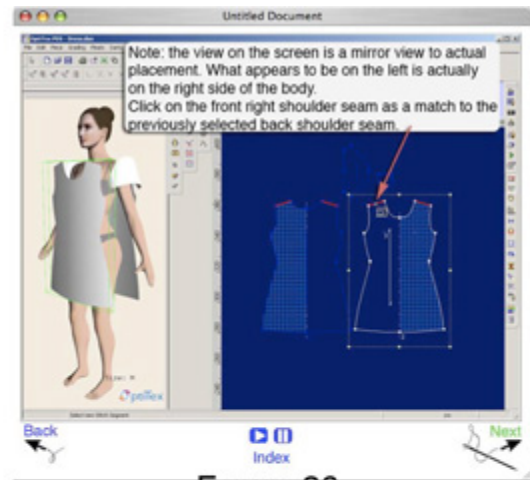


Frame 24





Frame 25



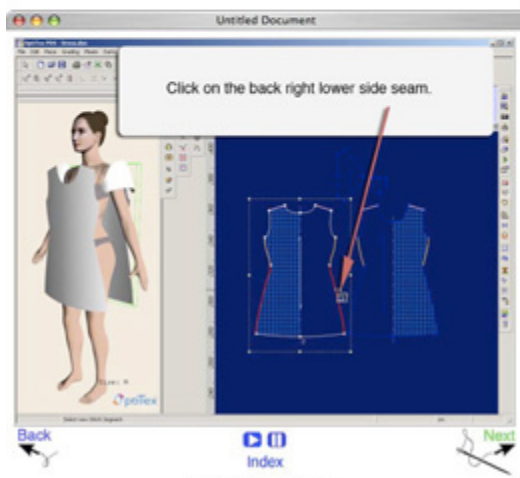
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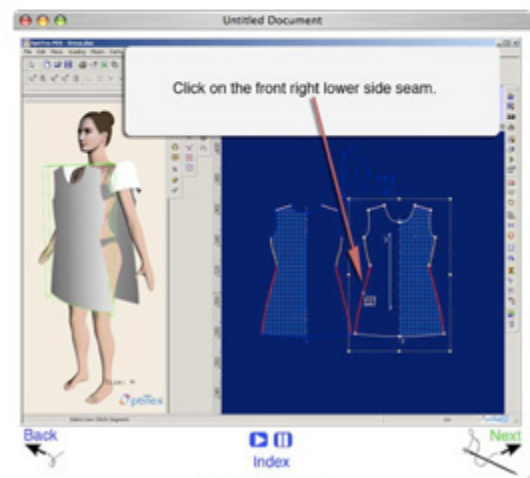
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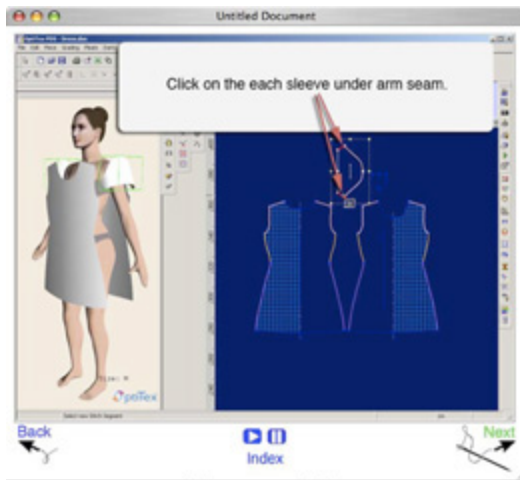
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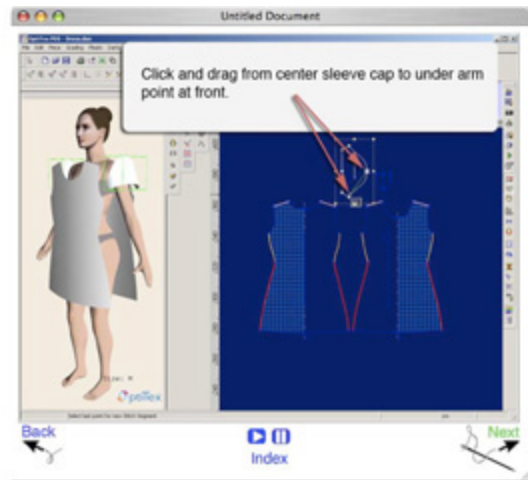
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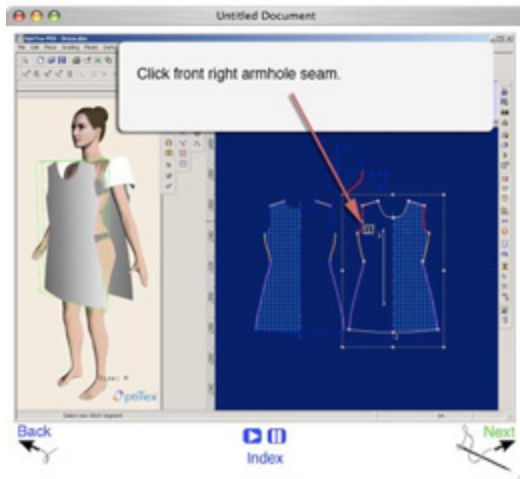
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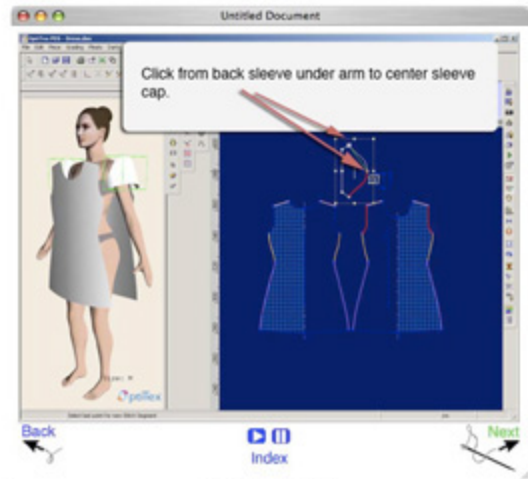
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Frame 32



Frame 33



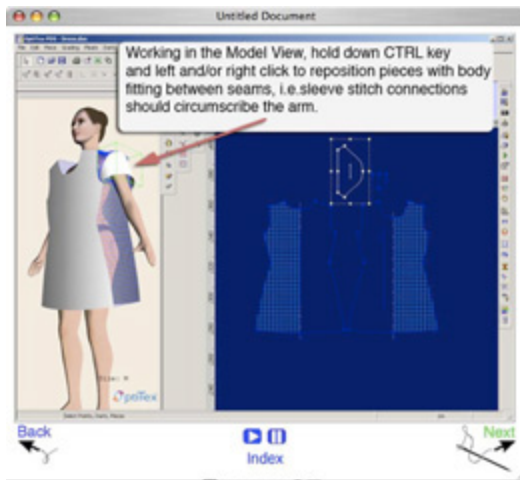
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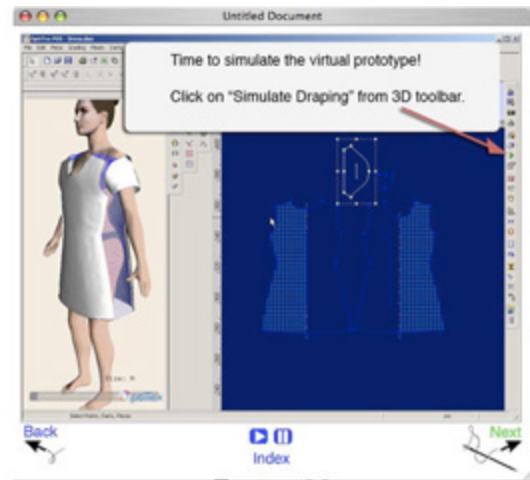
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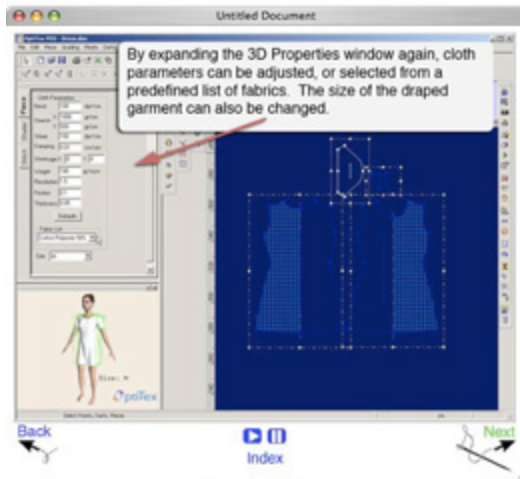
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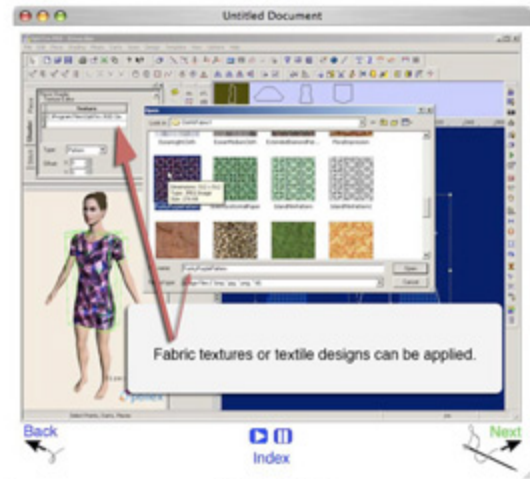
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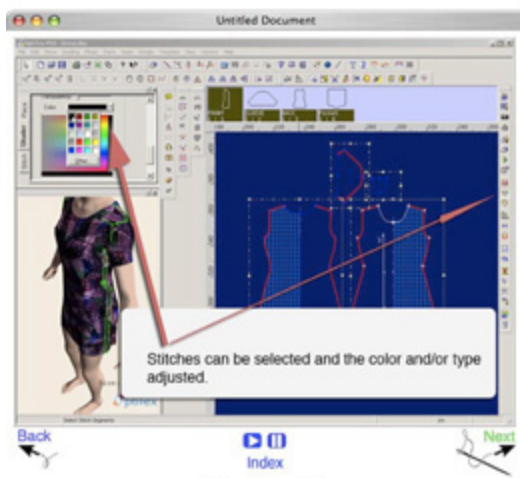
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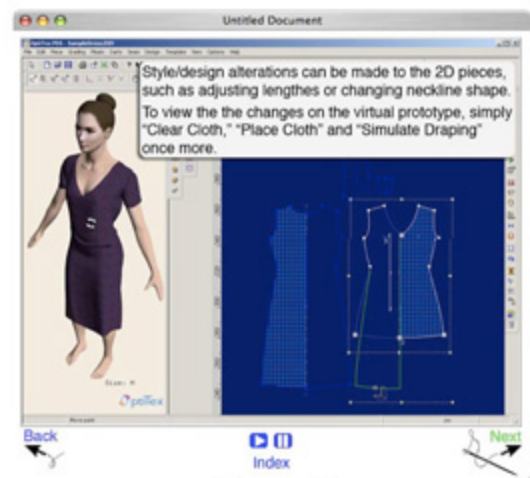
Frame 39



Frame 40

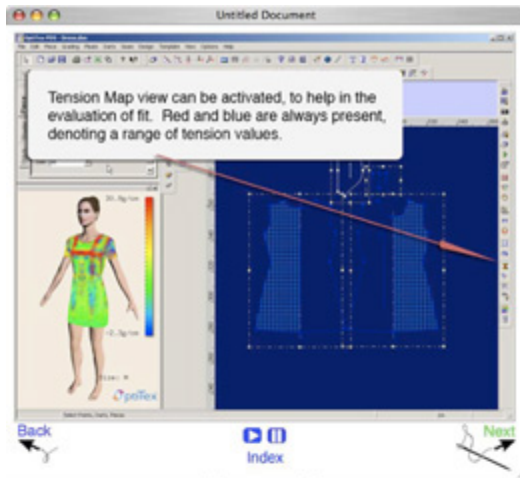


Frame 41

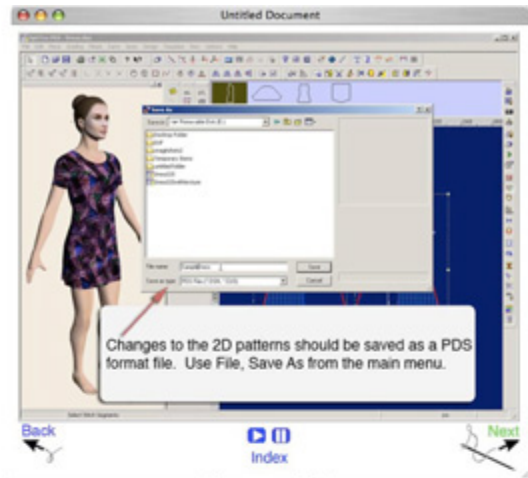


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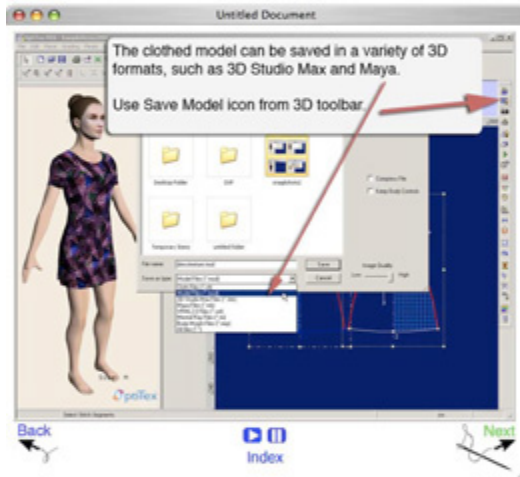




Frame 43



Frame 44



Frame 45



Frame 46



Frame 47



Frame 48

## APPENDIX F: SURVEY ITEMS

### Demographics

1. How old are you, in years? \_\_\_\_\_
2. What is your gender?  
Male                  Female
3. What is your current student classification?  
Freshman    Sophomore    Junior                  Senior                  Graduate

### Pattern Shape Exposure

4. Prior to undergraduate education, did you have any experience with clothing construction?  
Yes    No
5. Please select the your current apparel design course level:
  1. Currently enrolled in or completed a patternmaking course at the 200 level  
  
(have not yet taken any 300 level patternmaking / design course)
  2. Currently enrolled in or completed two or more patternmaking / design courses at the 300 or 400 level

### Computer Self-Efficacy Measure

Often in our work, either school or professional, we are told about software packages that are available to make work easier. For the following questions, imagine that you were given a new software package for some aspect of your work. It doesn't matter specifically what this software package does, only that it is intended to make your work easier and that you have never used it before.

The following questions ask you to indicate whether you could use this unfamiliar software package under a variety of conditions. For each of the

conditions, please indicate whether you think you would be able to complete the job using the software package. If you do not think you would be able to use the software package under the stated conditions, your choice would be "False" and you would select "0". If, for each condition you feel you could use the software package, i.e., "True," please rate your confidence about your first judgment, by circling a number from 1 to 10, where 1 indicates

"Not at all confident," 5 indicates "Moderately confident," and 10 indicates "Totally confident."

For example, consider the following sample item:

I COULD COMPLETE THE JOB USING THE SOFTWARE PACKAGE,,.

...if there was someone giving me step by step instructions.

False    True

Not at all Confident

Moderately Confident

Totally Confident

0      1      2      3      4      5      6      7      8      9      10

6. ...if there was no one around to tell me what to do as I go.
7. ...if I had never used a package like it before.
8. ...if I had only the software manuals for reference,
9. ...if I had seen someone else using it before trying it myself.
10. ...if I could call someone for help if I got stuck.
11. ...if someone else had helped me get started.
12. ...if I had a lot of time to complete the job for which the software was provided.
13. ...if I had just the built-in help facility for assistance.
14. ...if someone showed me how to do it first
15. ...if I had used similar packages before this one to do the same job.

### Surface Development Test

In this test you are to try to imagine or visualize how a piece of paper can be folded to form some kind of object. Look at the two drawings below. The drawing on the left is of a piece of paper, which can be folded on the dotted lines to form the object drawn at the right. You are to imagine the folding and are to figure out which of the lettered edges on the object are the same as the numbered edges on the piece of paper at the left. Write the letters of the answers in the numbered spaces at the far right.

Now try the practice problem below. Numbers 1 and 4 are already correctly marked for you.

*Note: Image removed for publication. Surface Development Test, VZ-3, Part 1, Practice Problem (Ekstrom et al., 1976).*

Note: The side of the flat piece marked with the X will always be the same as the side of the object marked with the X. Therefore, the paper must always be folded so that the X will be on the outside of the object.

In the above problem, if the side with edge 1 is folded around to form the back of the object, then edge 1 will be the same as edge H. If the side with edge 5 is folded back, then the side with edge 4 may be folded down so that edge 4 is the

same as edge C. The other answers are as follows: 2 is B; 3 is G; and 5 is H.

Notice that two of the answers can be the same.

Your score on this test will be the number of correct letters minus a fraction of the number of incorrect letters. Therefore, It will not be to your advantage to guess unless you are able to eliminate one of more of the answer choices are wrong.

16. *Note: Image removed for publication. Surface Development Test, VZ-3, Part 1, Problem #1 (Ekstrom et al., 1976).*

17. *Note: Image removed for publication. Surface Development Test, VZ-3, Part 1, Problem #2 (Ekstrom et al., 1976).*

18. *Note: Image removed for publication. Surface Development Test, VZ-3, Part 1, Problem #3 (Ekstrom et al., 1976).*

19. *Note: Image removed for publication. Surface Development Test, VZ-3, Part 1, Problem #4 (Ekstrom et al., 1976).*

20. *Note: Image removed for publication. Surface Development Test, VZ-3, Part 1, Problem #5 (Ekstrom et al., 1976).*

21. *Note: Image removed for publication. Surface Development Test, VZ-3, Part 1, Problem #6 (Ekstrom et al., 1976).*

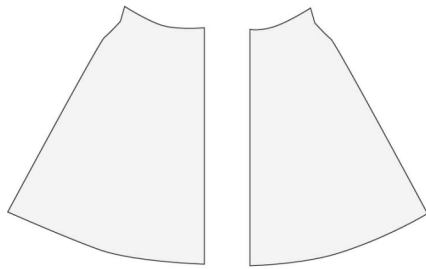
### **Apparel Spatial Visualization Test**

This test consists of 20 sets of pattern pieces, which can be constructed, in fabric to create a garment. To the right of each set of pattern pieces there are sketches of some garments. You are to decide which one of these garments can be made from the pattern pieces shown. The sketch always shows the outside, front

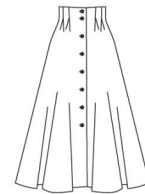


view of the garment. Remember: In this test there will always be a group of five (5) sketches, following each set of pattern pieces. In every group there is only one correct garment sketch. Study the set of pattern pieces carefully and decide which garment can be made from it.

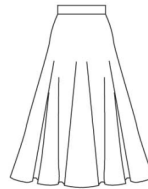
Show your choice by selecting the lettered button, which is the same as that of the garment you have chosen. Work as rapidly and as accurately as you can. If you are not sure of an answer, mark the choice, which is your best guess.



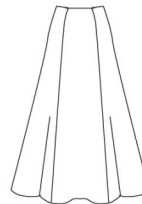
A



B



C

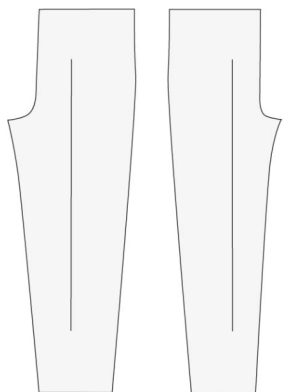


D

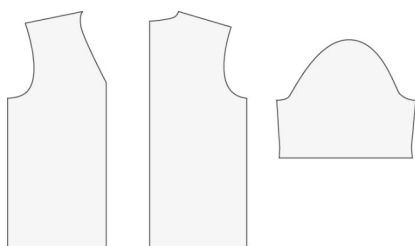


E

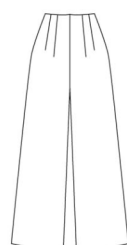
22.



23.



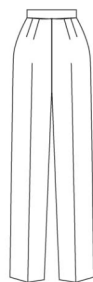
24.



A



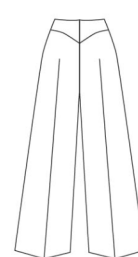
B



C



D



E



A



B



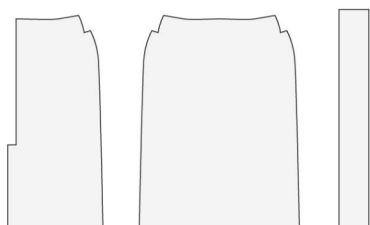
C



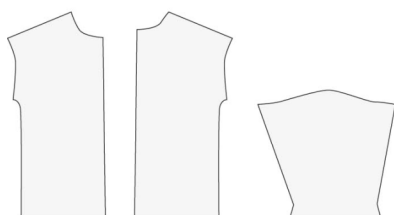
D



E



25.



26.



A



B



C



D



E



A



B



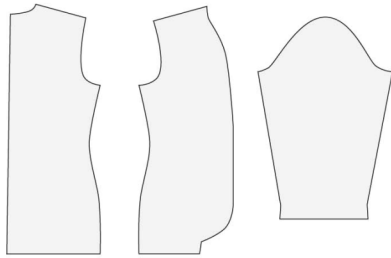
C



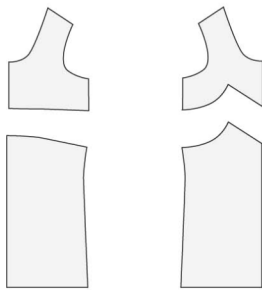
D



E



27.



28.



A



B



C



D



E



A



B



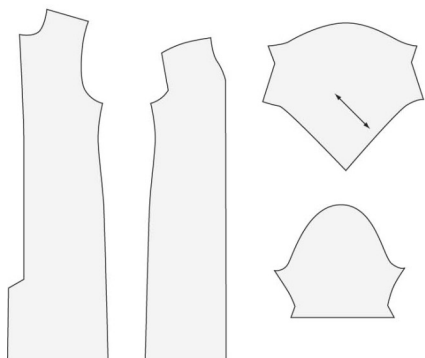
C



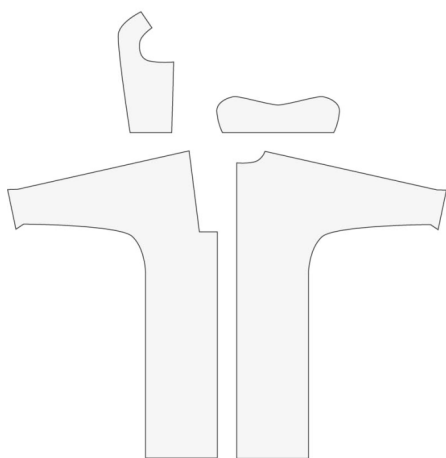
D



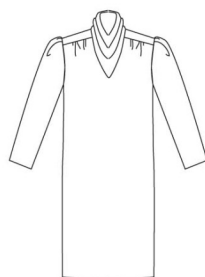
E



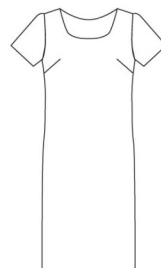
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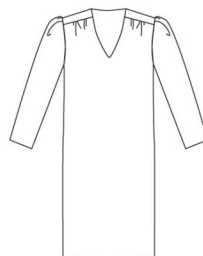
30.



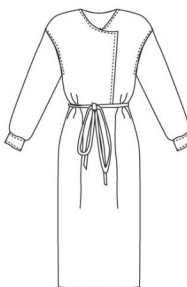
A



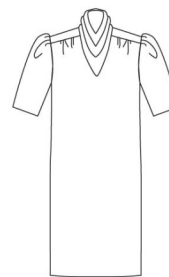
B



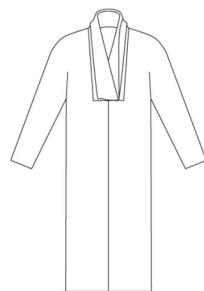
C



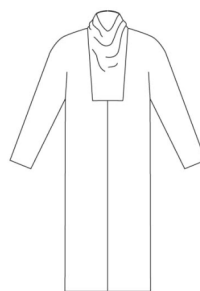
D



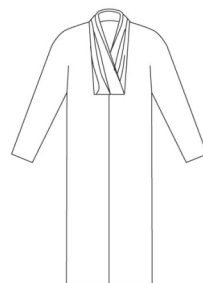
E



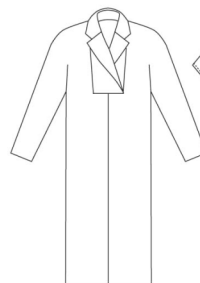
A



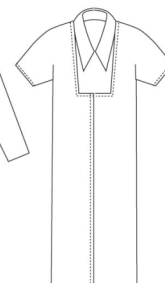
B



C

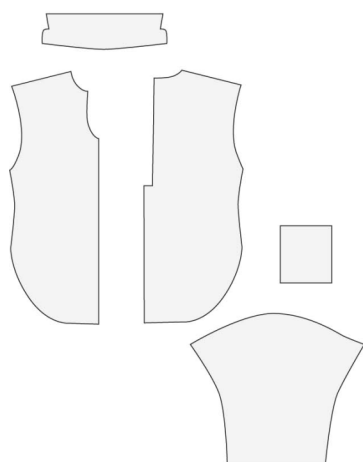


D

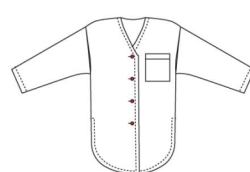
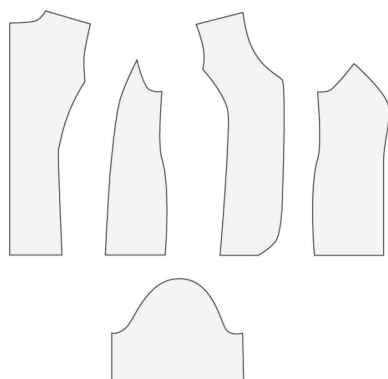


E

31.



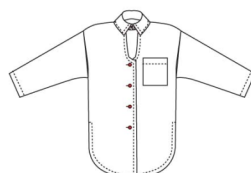
32.



A



B



C



D



E



A



B



C

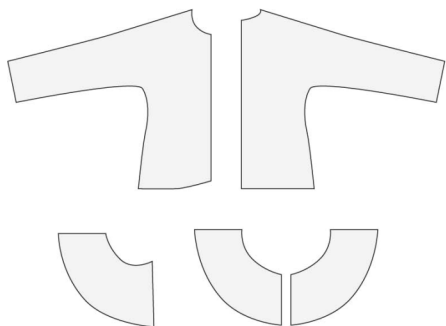


D

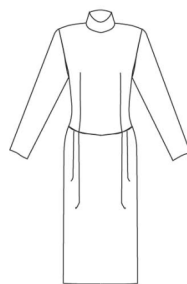
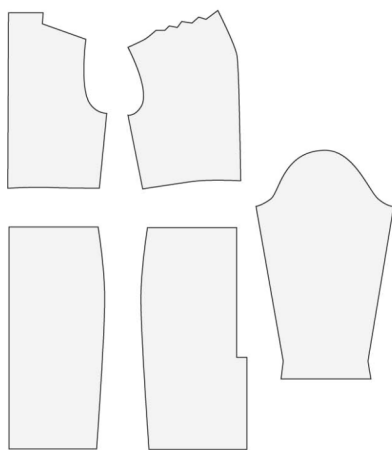


E

33.



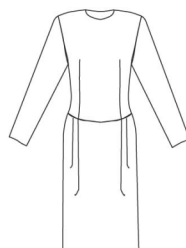
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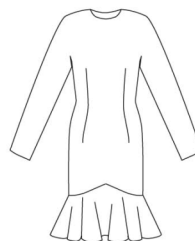
A



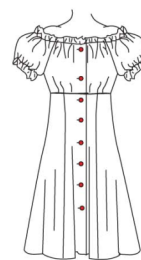
B



C



D



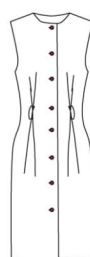
E



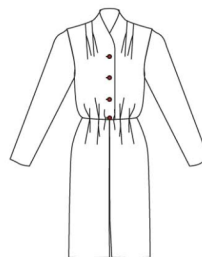
A



B



C

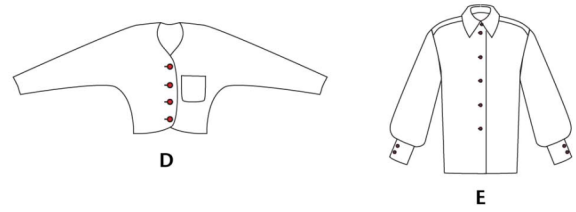
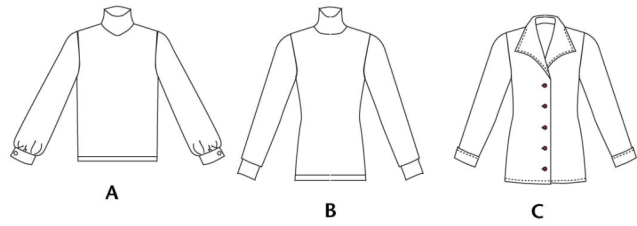
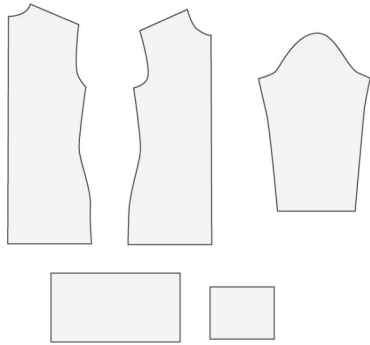


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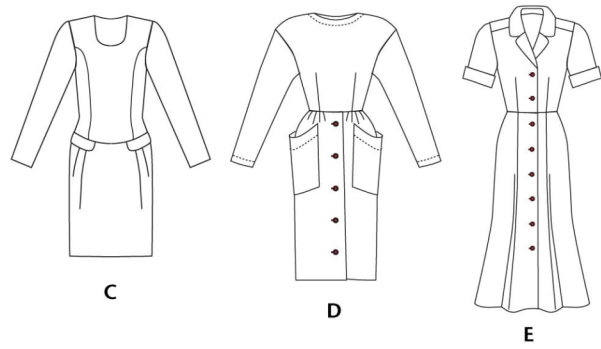
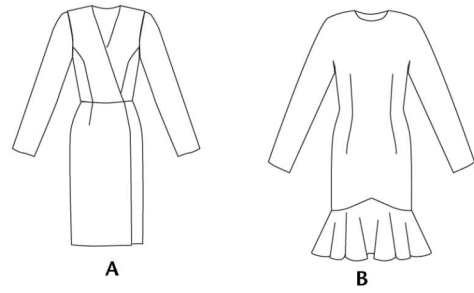
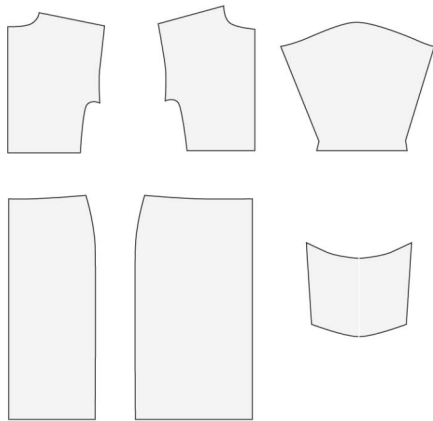


E

35.

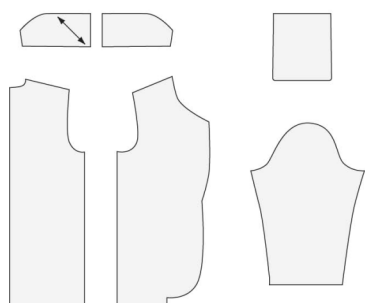


36.

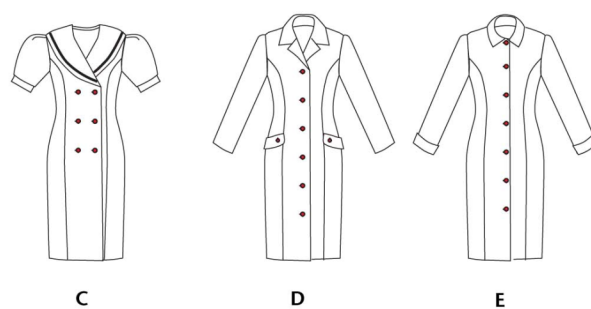
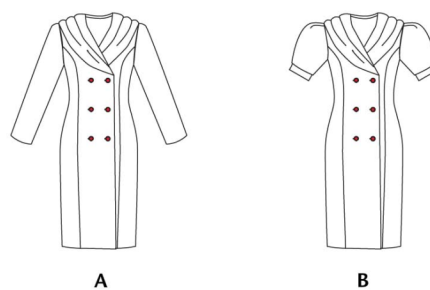
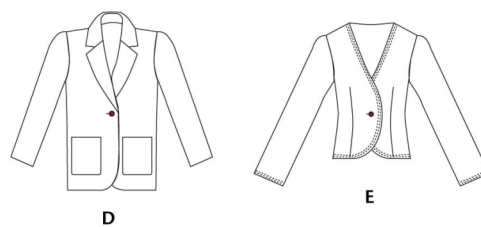
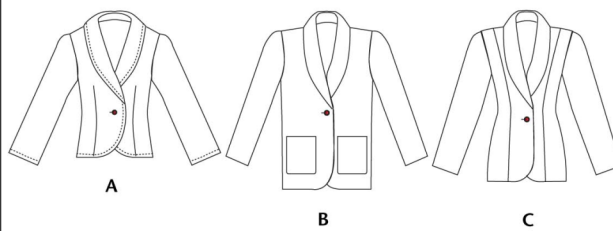
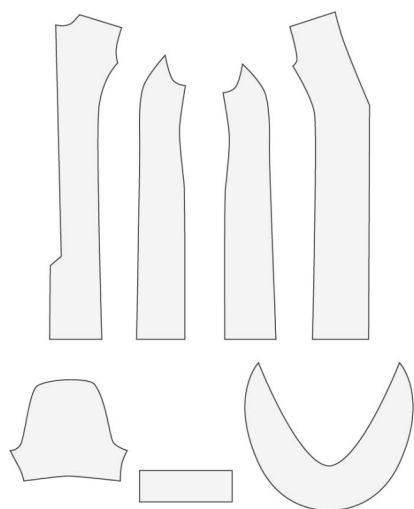




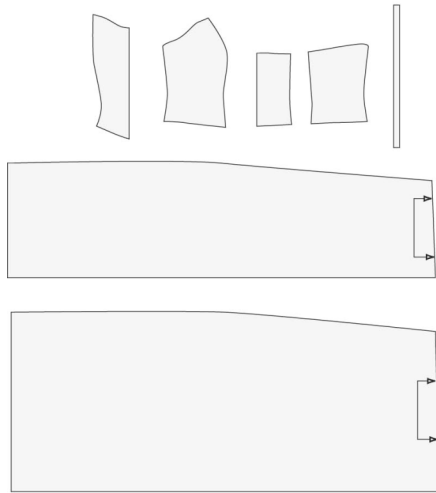
37.



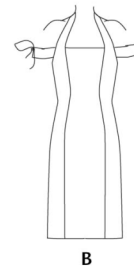
38.



39.



A



B



C

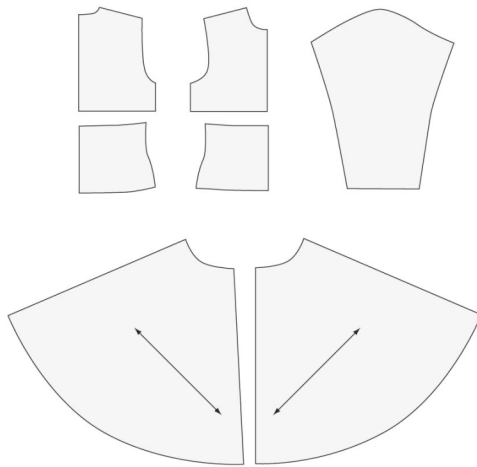


D



E

40.



A



B



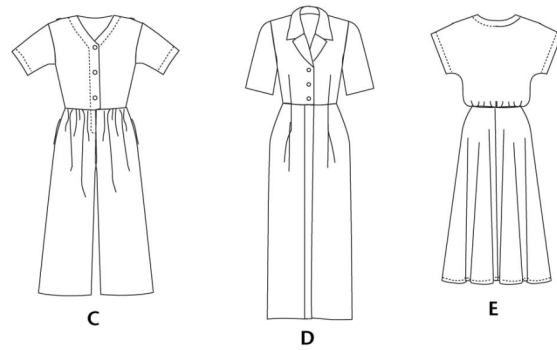
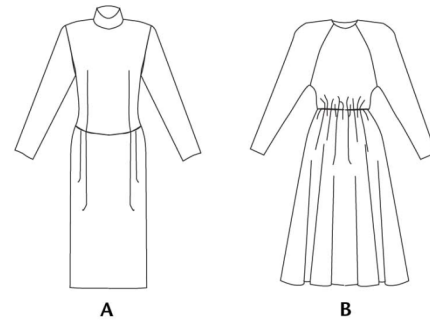
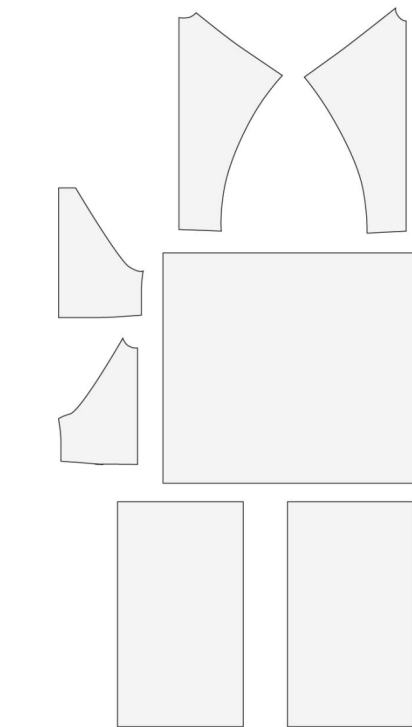
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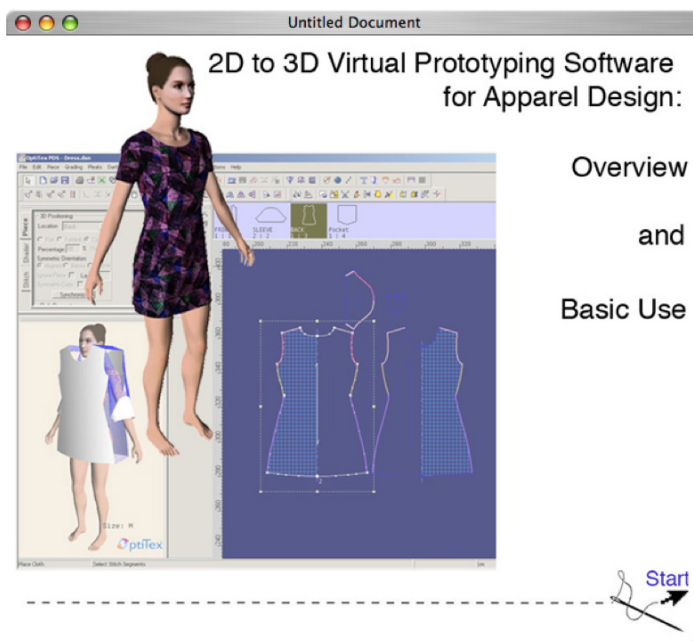
D



E



## 3D Virtual Prototyping Tutorial



### Perceived Ease of Use

**Unlikely** | extremely | quite | slightly | **neither** | slightly | quite | extremely | **Likely**

1            2            3            4            5            6            7

- 42. Learning to operate 3D virtual prototype simulations would be easy for me.
- 43. I would find it easy to get 3D virtual prototype simulations to do what I want it to do.
- 44. My interaction with 3D virtual prototype simulations would be clear and understandable.
- 45. I would find 3D virtual prototype simulations to be flexible to interact with.
- 46. It would be easy for me to become skillful at using 3D virtual prototype simulations.
- 47. I would find 3D virtual prototype simulations easy to use.

### Perceived Usefulness

**Unlikely** | extremely | quite | slightly | **neither** | slightly | quite | extremely | **Likely**

1            2            3            4            5            6            7

- 48. Using 3D virtual prototype simulations in my job would enable me to accomplish tasks more quickly.
- 49. Using 3D virtual prototype simulations would improve my job performance.
- 50. Using 3D virtual prototype simulations in my job would increase my productivity.
- 51. Using 3D virtual prototype simulations would enhance my effectiveness on the job.
- 52. Using 3D virtual prototype simulations would make it easier to do my job.
- 53. I would find 3D virtual prototype simulations useful in my job.
  
- 54. Please write any comments you have about your perception of 3D virtual prototyping software and its possible use in instruction of apparel design.
  
- 55. If you have requested to participate in one of the 3D virtual prototyping software hands-on sessions, please enter the first 4 digits of your student ID # in the field below. These digits will only be used for coding purposes and will not be retained with the data.

**Additional items from “Hands-on Follow-up”**

Do you feel that working with 3D virtual prototype garments could reduce the number of physical sample garments constructed during the design process?

1. Yes                      2. No

Do you feel 3D virtual prototyping software would be useful for instruction of apparel patternmaking / design concepts?

1. Yes                      2. No

At which course level(s) do you feel working with 3D virtual prototyping software would be appropriate?

1. 100 level                      2. 200 level    3. 300 level    4. 400 level    5. 500 level

Do you feel that tutorials such as the one seen in this survey would be useful for learning 3D virtual prototyping software?

1. Yes                      2. No

Please describe other instructional tools that might increase your level of confidence in using 3D virtual prototyping software, i.e. tutorials, handouts, lab demonstrations, projects, etc.

Now that you've participated in the hands-on session, please write any other comments you have about your perception of 3D virtual prototyping software and its possible use in instruction of apparel design.

## APPENDIX G: RECRUITMENT EMAIL

**From:** Sandra Stewart <sandras@iastate.edu>  
**Subject:** 2D/3D Virtual Prototyping - Research Participant Opportunity  
**Date:** December 4, 2007 12:47:27 PM CST

Dear Apparel Design Students,

I am Sandra Stewart, a graduate student currently pursuing my master's degree in Textiles and Clothing. I am conducting research related to the potential classroom use of 3D virtual prototyping software for apparel design. This software was recently featured on Bravo TV's "Tim Gunn's Guide to Style" and is also in use by industry leaders such as Target Corporation and Tommy Hilfiger (www.optitex.com).

As you are a student currently enrolled in an apparel design course, I would like to request your participation in this research. One benefit to you will be introduction to the advanced technology via an online tutorial. Small groups of survey participants will also have the opportunity to interact with the software during scheduled hands-on sessions.

The tutorial and survey may be accessed online, through the WebCT GOLD course, "TC Stewart 1." Please be sure to use a WebCT compatible web browser. Survey & tutorial have been tested on Safari for the Mac and Internet Explorer for PCs. If using Internet Explorer you may have to confirm "displaying nonsecure items" for question #42 (viewing tutorial) It should take between 35 - 45 minutes to answer the survey items (viewing tutorial included). Participation is completely voluntary, you can skip any questions you do not wish to answer, and since no identifiers will be retained with the data, survey results will remain confidential.

Volunteers who complete the online survey and who also have interest in participating in a hands-on session should reply to sandras@iastate.edu with their availability and preference for the following dates and times:

12/4 Tuesday	-	-	-	-	-
	3 pm				
12/5 Wednesday	-	10 am	11 am	1 pm	2 pm 3 pm
12/6 Thursday	9 am	10 am	11 am	-	- 3 pm

A confirmation email will be sent indicating which session to attend. Due to a limited number of seats, interested participants will be assigned to sessions on a first come, first serve basis. The online survey should be completed before participating in the hands-on session.

If you have any questions about this research, or the purpose of the study, please contact me, Sandra Stewart, at sandras@iastate.edu (515 314 7430) or Dr. Jean Parsons at jparsons@iastate.edu.

Results of this study will help educators make better decisions about how 3D virtual prototyping technology could be used in the classroom. Your time and participation would be greatly appreciated.

Thank you,  
 Sandra Stewart  
 M.S. Candidate, Textiles and Clothing Program  
 Apparel, Education Studies, and Hospitality Management Department

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